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Chen

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(54) **LOCATION MODEL UPDATING APPARATUS AND POSITION ESTIMATING METHOD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(30) **Foreign Application Priority Data**

Sep. 27, 2013 (JP) 2013-202018

(51) **Int. Cl.**

H04M 1/10	(2006.01)
H04W 64/00	(2009.01)
G01S 5/00	(2006.01)

(52) **U.S. Cl.**

CPC . ***H04W 64/00*** (2013.01); ***G01S 5/00*** (2013.01)

(58) **Field of Classification Search**

CPC H04W 64/00; H04W 4/02; H04W 4/023; G01S 5/0252; G01S 2205/008; G01S 5/0009; G01S 5/0054

USPC 455/456.1

See application file for complete search history.

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JP	2013-059237	3/2013

* cited by examiner

Primary Examiner — Don N Vo

(74) *Attorney, Agent, or Firm* — Fujitsu Patent Center

(57) **ABSTRACT**

A location model updating apparatus generates attribute data including an attribute of a location and an attribute between locations. A peripheral location is extracted by including each location from a current location of a terminal apparatus to a first front as a member of a definite peripheral location list, including each location from the first front to a second front as a member of a candidate peripheral location list, and updating each location that is a member of the definite peripheral location list and exists from the current location to the first front, and each location that is a member of the candidate peripheral location list and exists from the first front to the second front, using the current location of the terminal apparatus as a query. Data of a peripheral location model of the extracted peripheral location is transmitted to the terminal apparatus.

12 Claims, 22 Drawing Sheets

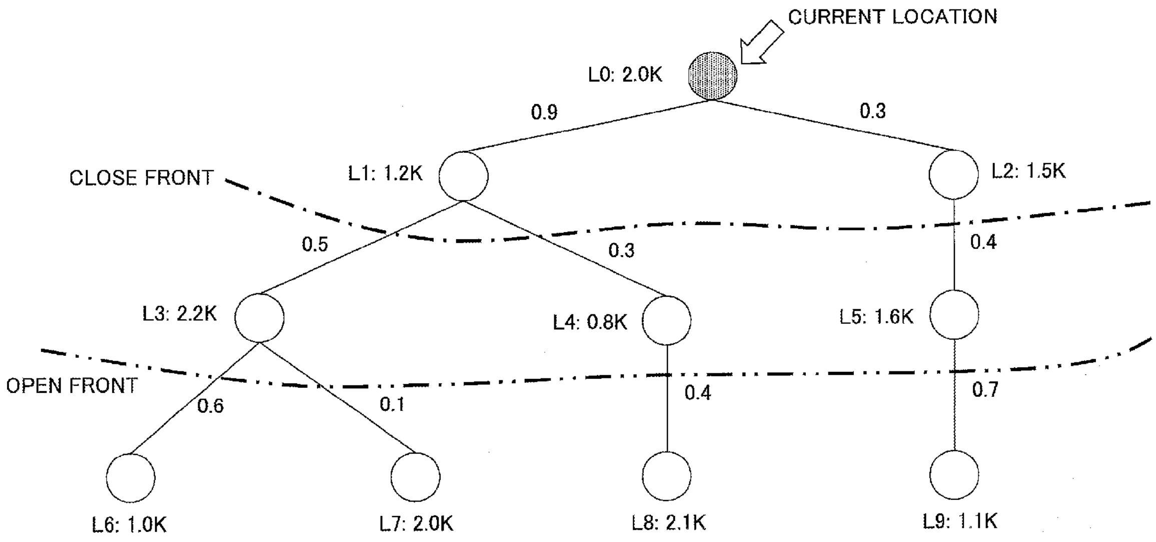


FIG.1

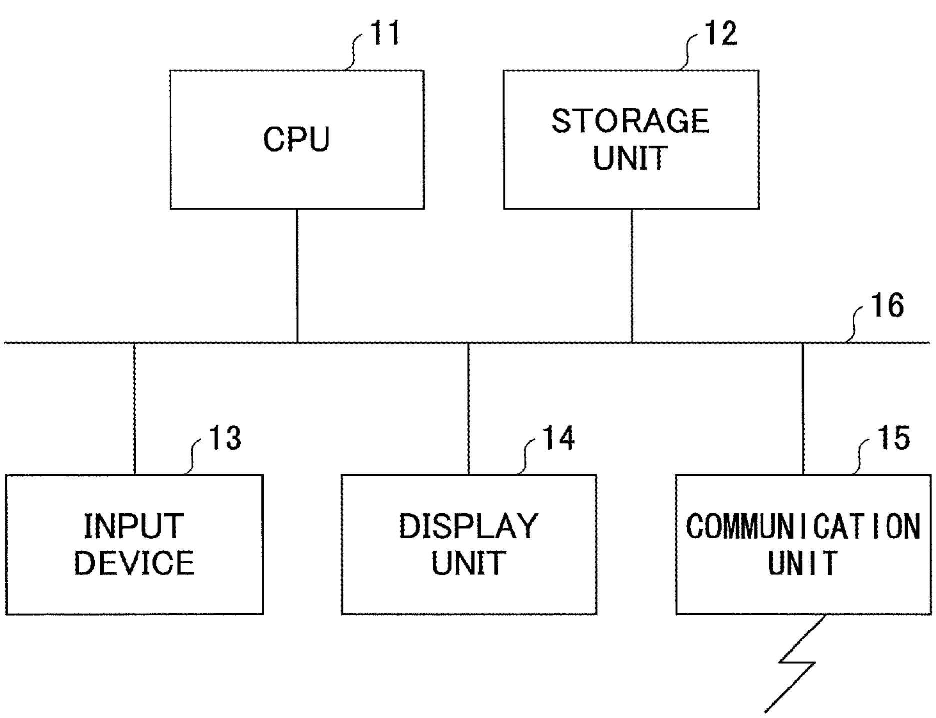

1
11
12
CPU
STORAGE UNIT
16
13
14
15
INPUT DEVICE
DISPLAY UNIT
COMMUNICATION UNIT

FIG.2

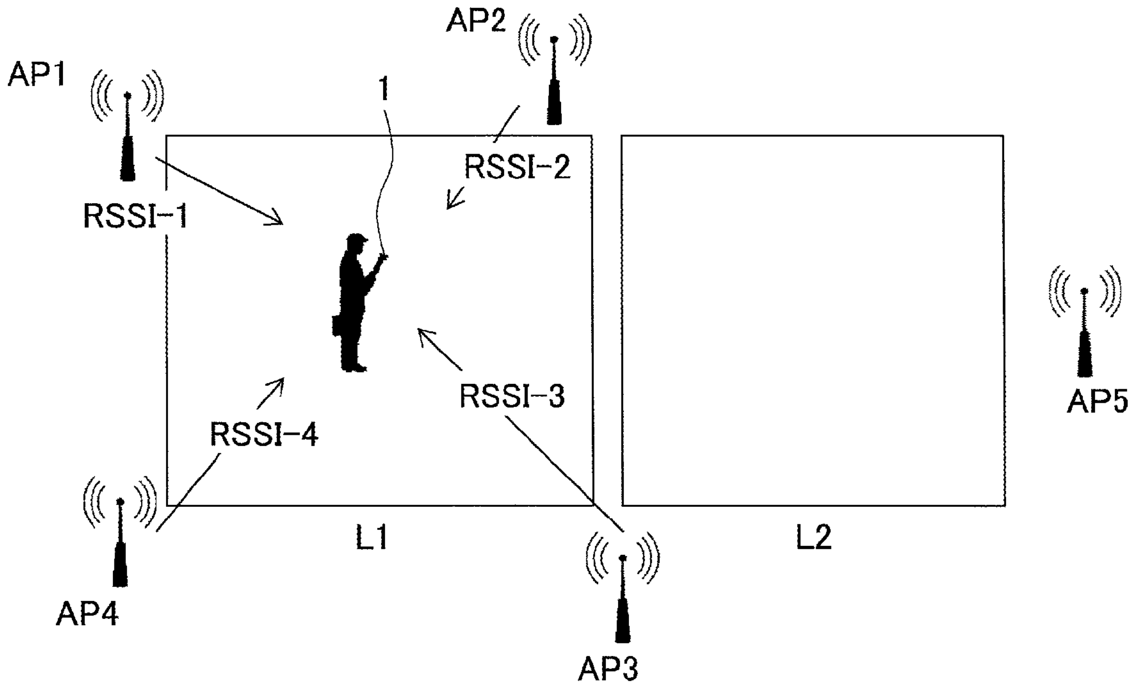


FIG.3

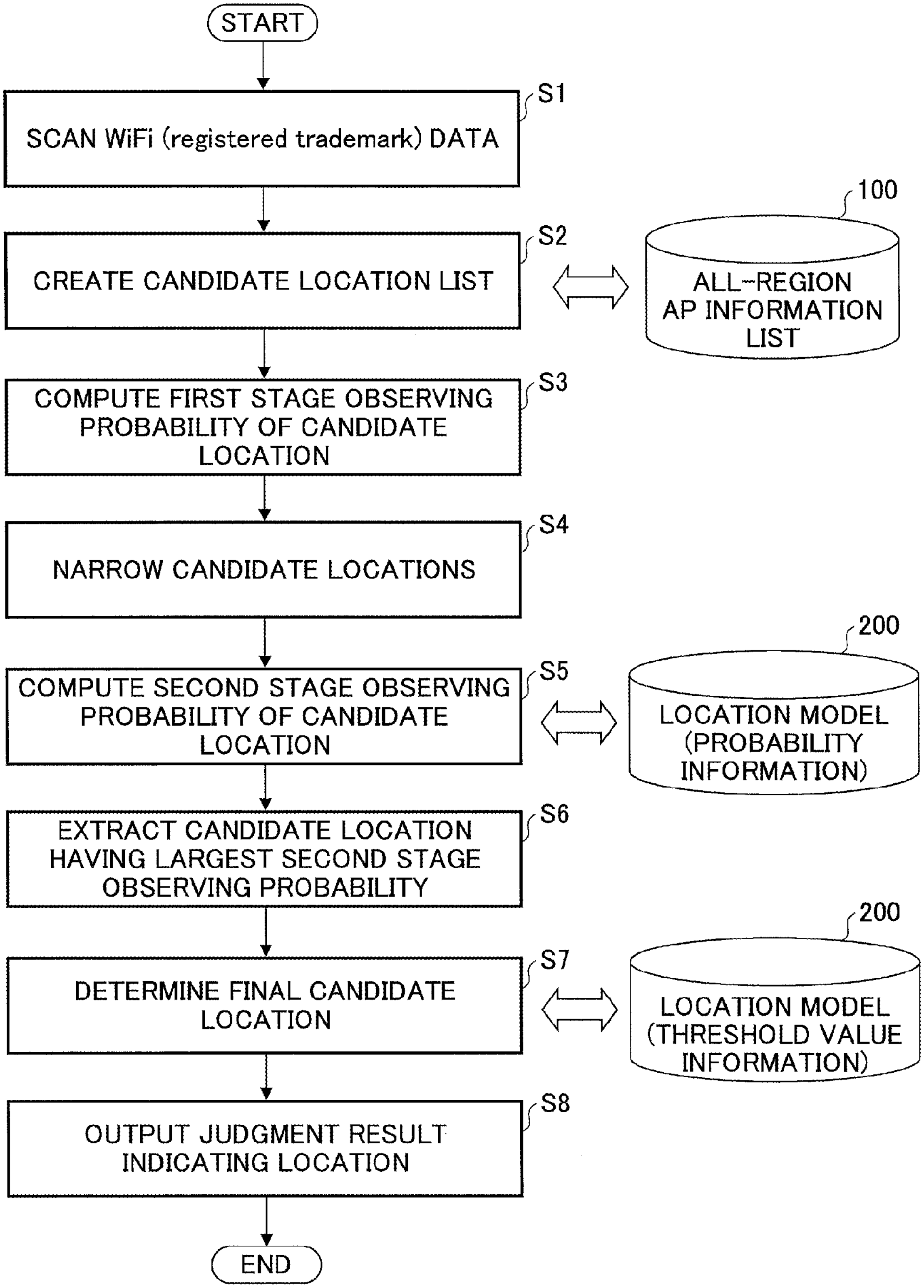

START
S1
SCAN WiFi (registered trademark) DATA
S2
CREATE CANDIDATE LOCATION LIST
100
ALL-REGION AP INFORMATION LIST
S3
COMPUTE FIRST STAGE OBSERVING PROBABILITY OF CANDIDATE LOCATION
S4
NARROW CANDIDATE LOCATIONS
S5
COMPUTE SECOND STAGE OBSERVING PROBABILITY OF CANDIDATE LOCATION
200
LOCATION MODEL (PROBABILITY INFORMATION)
S6
EXTRACT CANDIDATE LOCATION HAVING LARGEST SECOND STAGE OBSERVING PROBABILITY
S7
DETERMINE FINAL CANDIDATE LOCATION
200
LOCATION MODEL (THRESHOLD VALUE INFORMATION)
S8
OUTPUT JUDGMENT RESULT INDICATING LOCATION
END

FIG.4

100

AP NUMBER	MAC ADDRESS OF AP	AP COVERING LOCATION LIST			
1	M1	LOCATION NAME L1	LOCATION NAME L2	LOCATION NAME L3	······
2	M2	LOCATION NAME L1	LOCATION NAME L2	LOCATION NAME L3	······
⋮	⋮	⋮	⋮	⋮	⋮

FIG.5

200

LOCA-TION NUMBER	LOCA-TION NAME	THRESHOLD VALUE	OBSERVABLE AP LIST																	
			MAC ADDRESS						MAC ADDRESS						MAC ADDRESS					
			MISSING PROBA-BILITY	OBSERV-ING PROBA-BILITY	OBSERVING PROBABILITY FOR EACH STRENGTH LEVEL				MISSING PROBA-BILITY	OBSERV-ING PROBA-BILITY	OBSERVING PROBABILITY FOR EACH STRENGTH LEVEL				MISSING PROBA-BILITY	OBSERV-ING PROBA-BILITY	OBSERVING PROBABILITY FOR EACH STRENGTH LEVEL			
					1	2	3	4			1	2	3	4			1	2	3	4
1	L1																			
2	L2																			
⋮																				

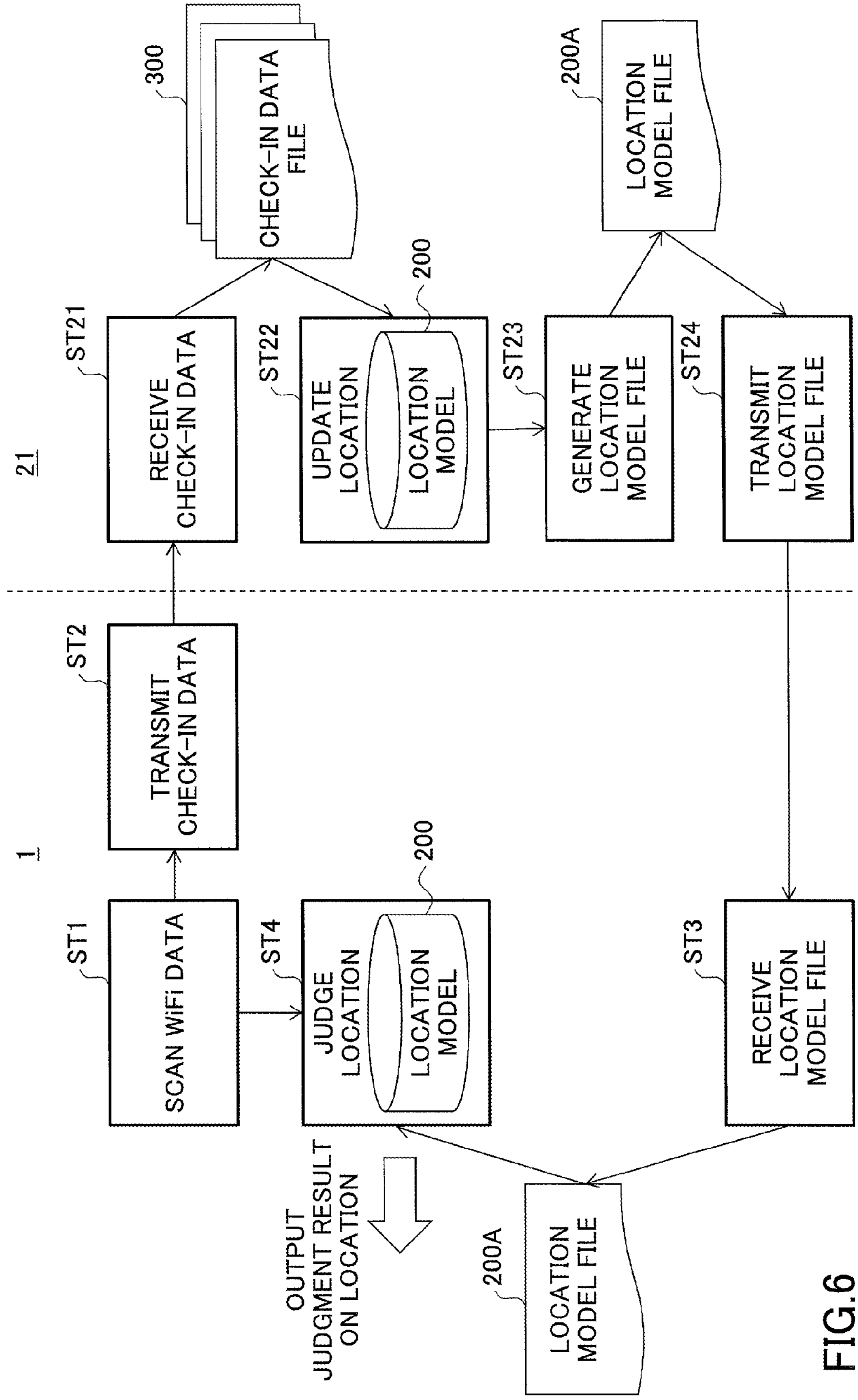
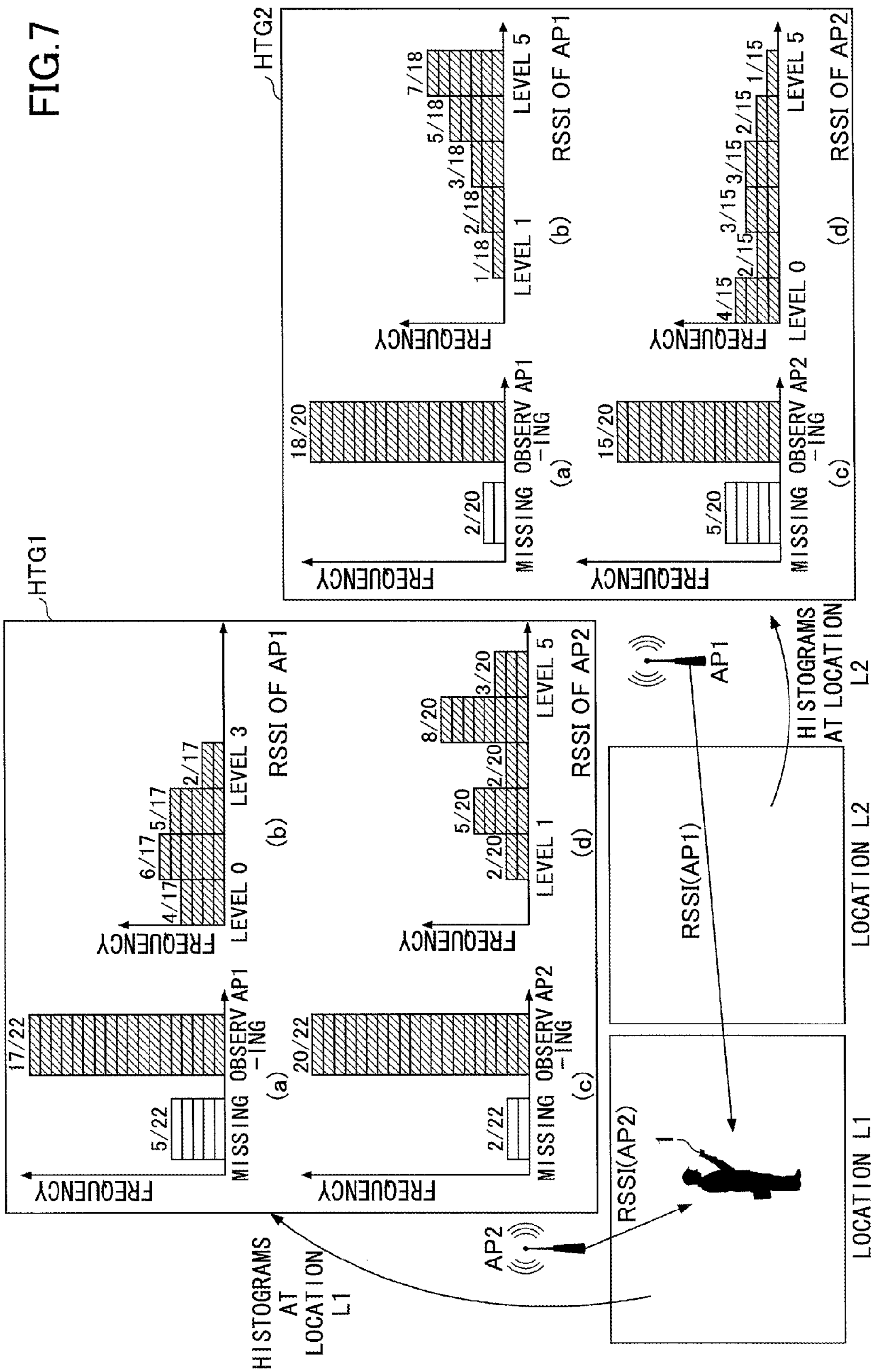

1
21
ST1
SCAN WiFi DATA
ST2
TRANSMIT CHECK-IN DATA
ST21
RECEIVE CHECK-IN DATA
300
CHECK-IN DATA FILE
ST22
UPDATE LOCATION
200
LOCATION MODEL
ST23
GENERATE LOCATION MODEL FILE
200A
LOCATION MODEL FILE
ST24
TRANSMIT LOCATION MODEL FILE
ST3
RECEIVE LOCATION MODEL FILE
200A
LOCATION MODEL FILE
ST4
JUDGE LOCATION
200
LOCATION MODEL
OUTPUT JUDGMENT RESULT ON LOCATION

FIG.6

FIG.7


HTG1
HTG2
FREQUENCY
5/22
17/22
MISSING
OBSERV-ING
AP1
(a)
4/17
6/17
5/17
2/17
LEVEL 0
LEVEL 3
(b)
RSSI OF AP1
2/22
20/22
AP2
(c)
2/20
5/20
2/20
8/20
3/20
LEVEL 1
LEVEL 5
(d)
RSSI OF AP2
2/20
18/20
1/18
2/18
3/18
5/18
7/18
5/20
15/20
4/15
2/15
3/15
3/15
2/15
1/15
HISTOGRAMS AT LOCATION L1
HISTOGRAMS AT LOCATION L2
RSSI(AP2)
RSSI(AP1)
LOCATION L1
LOCATION L2

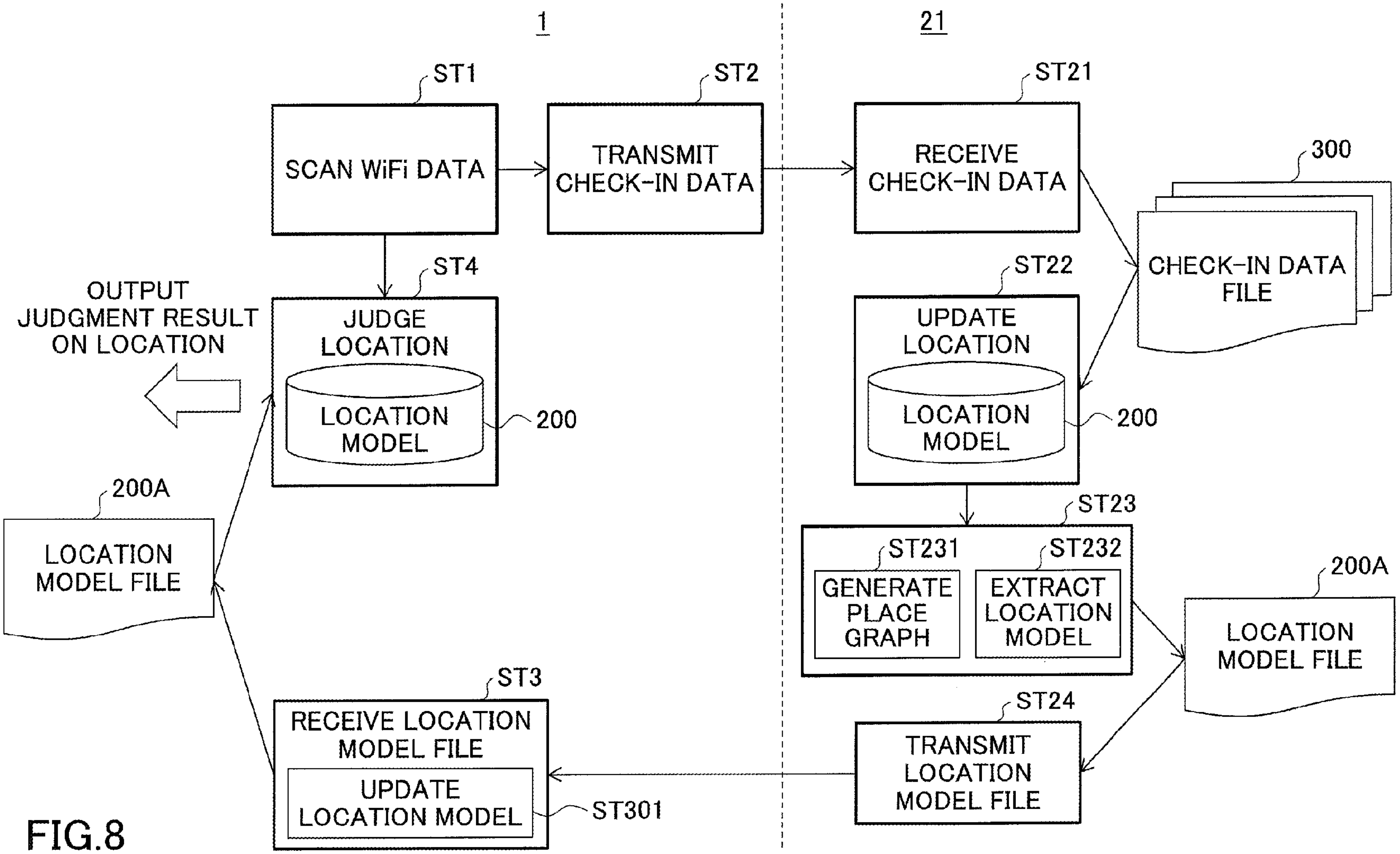

1
21
ST1
SCAN WiFi DATA
ST2
TRANSMIT CHECK-IN DATA
ST21
RECEIVE CHECK-IN DATA
300
CHECK-IN DATA FILE
ST4
JUDGE LOCATION
LOCATION MODEL
200
OUTPUT JUDGMENT RESULT ON LOCATION
ST22
UPDATE LOCATION
LOCATION MODEL
200
200A
LOCATION MODEL FILE
ST23
ST231
GENERATE PLACE GRAPH
ST232
EXTRACT LOCATION MODEL
200A
LOCATION MODEL FILE
ST3
RECEIVE LOCATION MODEL FILE
UPDATE LOCATION MODEL
ST301
ST24
TRANSMIT LOCATION MODEL FILE

FIG.8

FIG.9

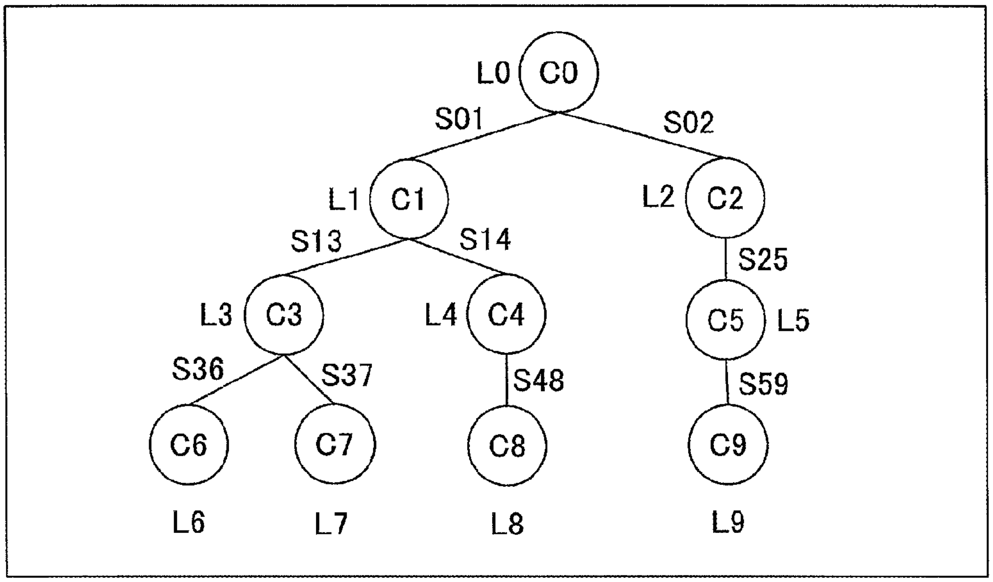

L0
C0
S01
S02
L1
C1
L2
C2
S13
S14
S25
L3
C3
L4
C4
C5
L5
S36
S37
S48
S59
C6
C7
C8
C9
L6
L7
L8
L9

FIG.10

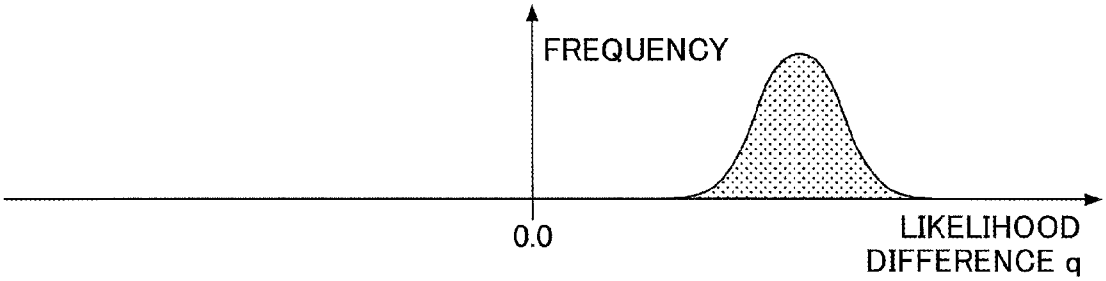

FREQUENCY
0.0
LIKELIHOOD
DIFFERENCE q

FIG.11

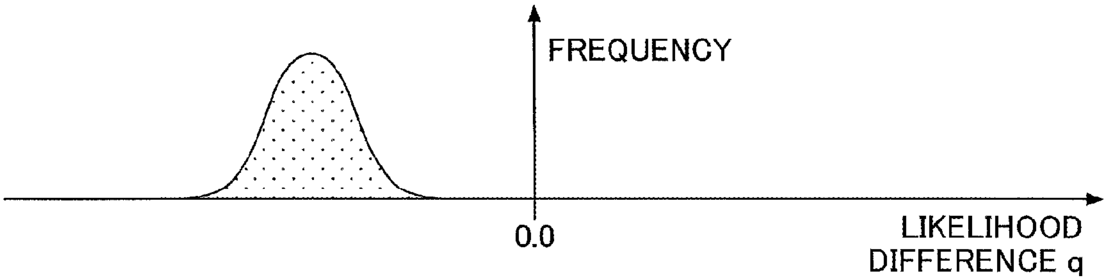

FREQUENCY
0.0
LIKELIHOOD DIFFERENCE q

FIG.12

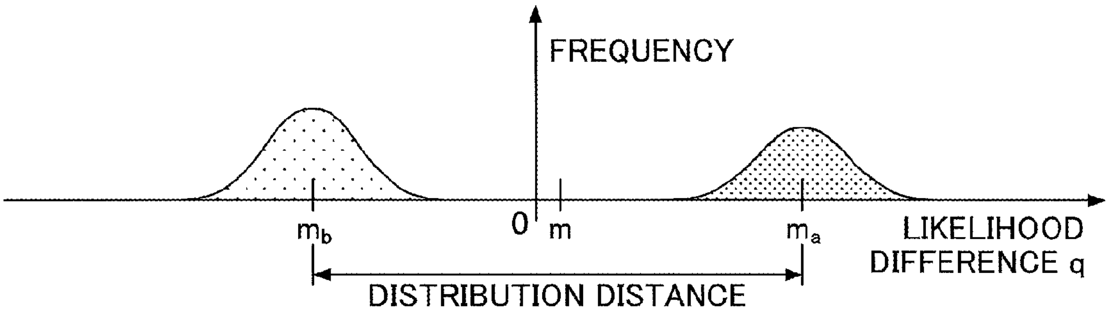

FREQUENCY
m_b
0
m
m_a
LIKELIHOOD DIFFERENCE q
DISTRIBUTION DISTANCE

FIG.13

	LOCATION L0	LOCATION L1	LOCATION L2	...
LOCATION L0	—	S01	S02	
LOCATION L1		—	S12	
LOCATION L2			—	
...				

FIG.14

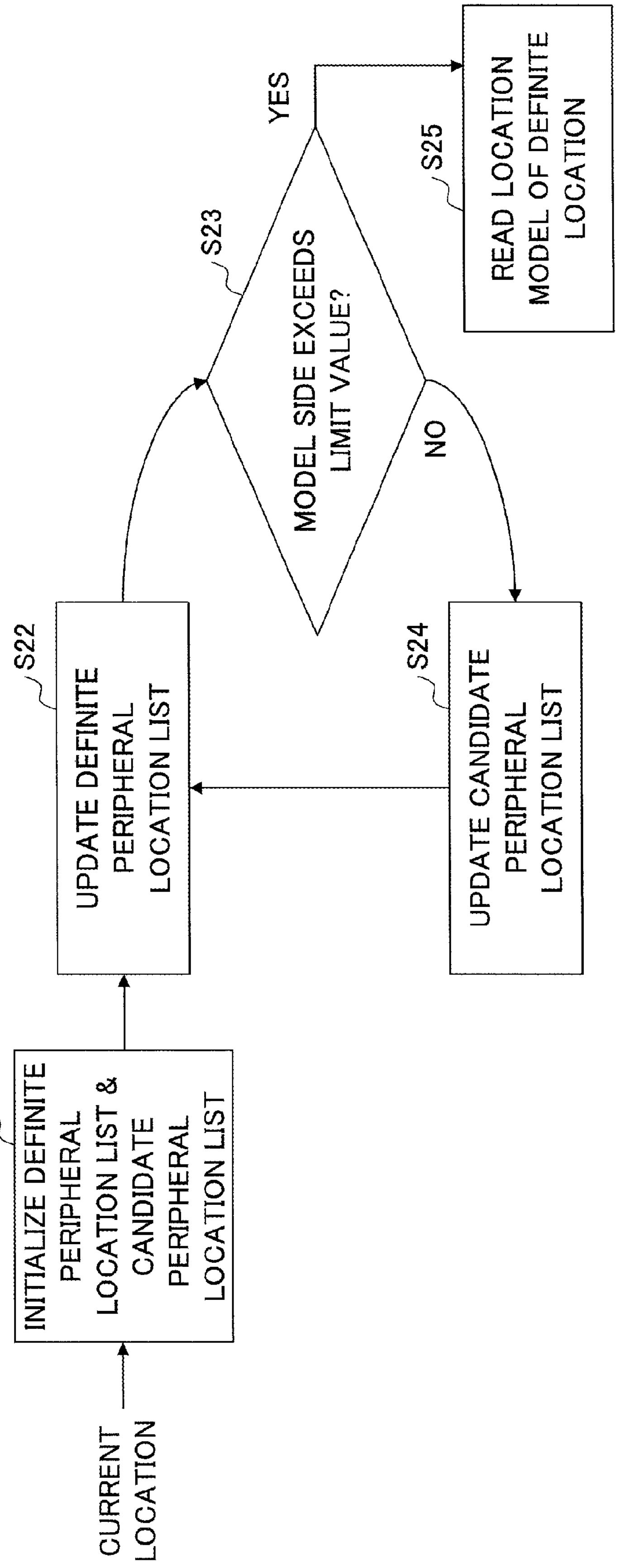

CURRENT LOCATION
S21
INITIALIZE DEFINITE PERIPHERAL LOCATION LIST & CANDIDATE PERIPHERAL LOCATION LIST
S22
UPDATE DEFINITE PERIPHERAL LOCATION LIST
S23
MODEL SIDE EXCEEDS LIMIT VALUE?
YES
NO
S24
UPDATE CANDIDATE PERIPHERAL LOCATION LIST
S25
READ LOCATION MODEL OF DEFINITE LOCATION

FIG.15

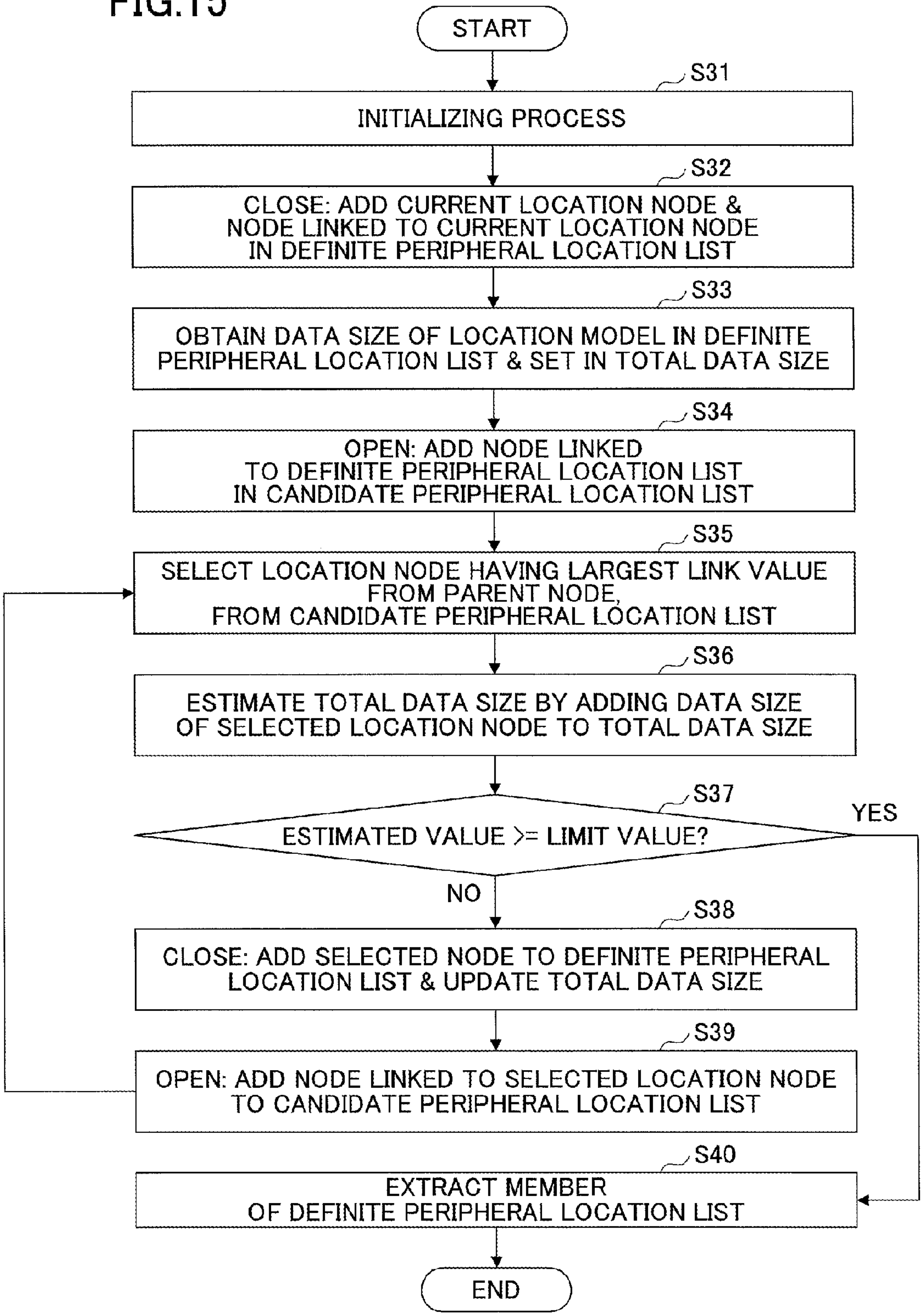

START
S31
INITIALIZING PROCESS
S32
CLOSE: ADD CURRENT LOCATION NODE & NODE LINKED TO CURRENT LOCATION NODE IN DEFINITE PERIPHERAL LOCATION LIST
S33
OBTAIN DATA SIZE OF LOCATION MODEL IN DEFINITE PERIPHERAL LOCATION LIST & SET IN TOTAL DATA SIZE
S34
OPEN: ADD NODE LINKED TO DEFINITE PERIPHERAL LOCATION LIST IN CANDIDATE PERIPHERAL LOCATION LIST
S35
SELECT LOCATION NODE HAVING LARGEST LINK VALUE FROM PARENT NODE, FROM CANDIDATE PERIPHERAL LOCATION LIST
S36
ESTIMATE TOTAL DATA SIZE BY ADDING DATA SIZE OF SELECTED LOCATION NODE TO TOTAL DATA SIZE
S37
ESTIMATED VALUE >= LIMIT VALUE?
YES
NO
S38
CLOSE: ADD SELECTED NODE TO DEFINITE PERIPHERAL LOCATION LIST & UPDATE TOTAL DATA SIZE
S39
OPEN: ADD NODE LINKED TO SELECTED LOCATION NODE TO CANDIDATE PERIPHERAL LOCATION LIST
S40
EXTRACT MEMBER OF DEFINITE PERIPHERAL LOCATION LIST
END

FIG.16

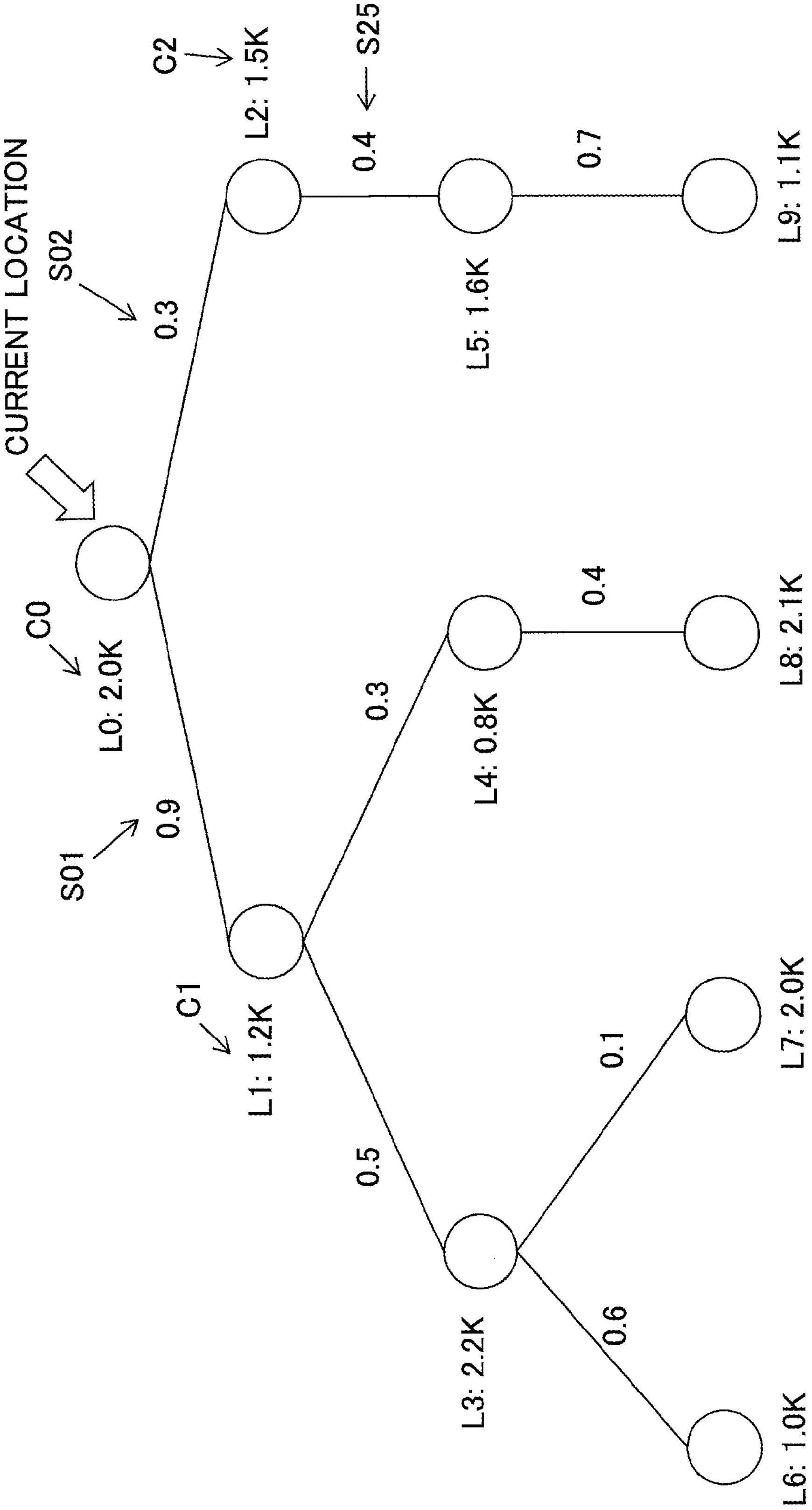

CURRENT LOCATION
C0
L0: 2.0K
S01
0.9
S02
0.3
C1
L1: 1.2K
C2
L2: 1.5K
0.5
0.3
0.4
S25
L3: 2.2K
L4: 0.8K
L5: 1.6K
0.6
0.1
0.4
0.7
L6: 1.0K
L7: 2.0K
L8: 2.1K
L9: 1.1K

FIG.17

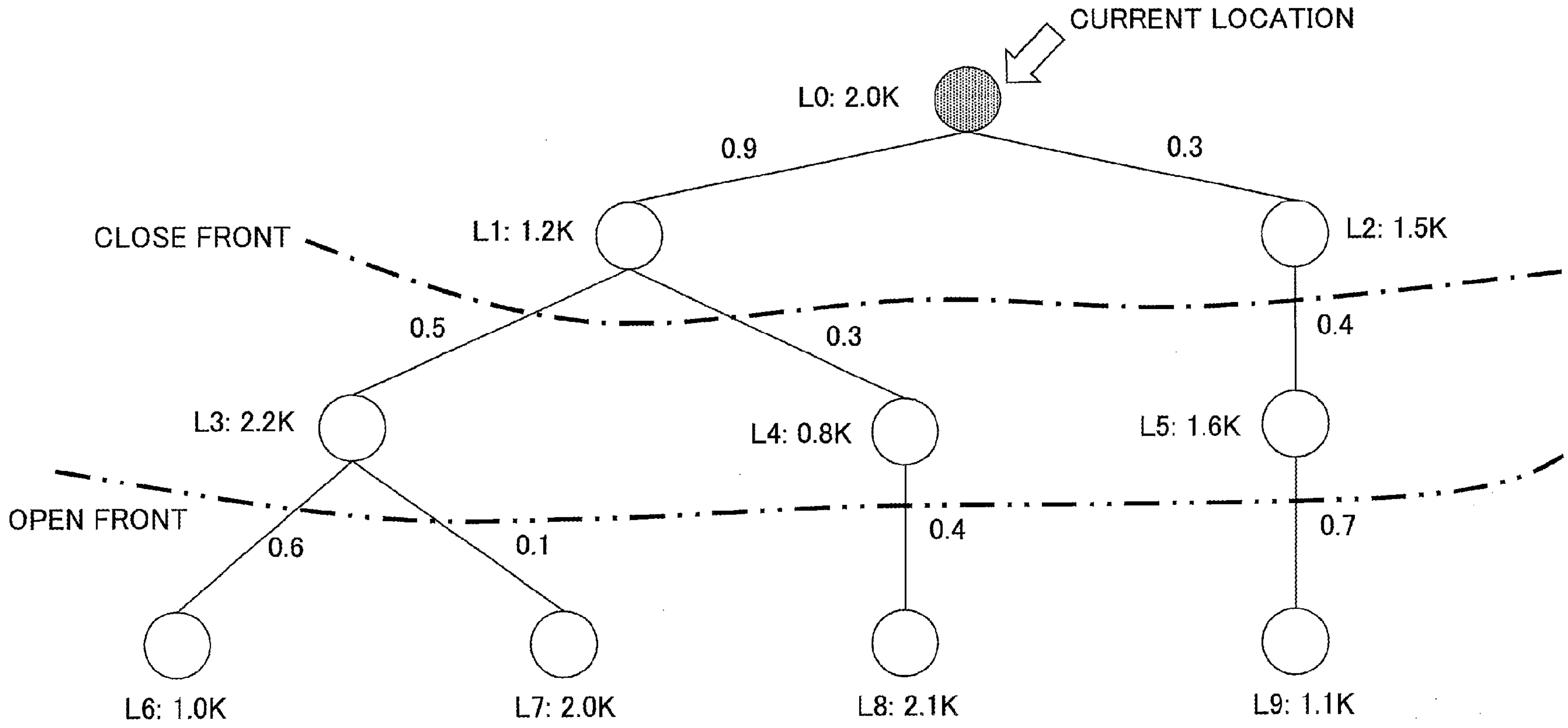

CURRENT LOCATION
L0: 2.0K
0.9
0.3
L1: 1.2K
L2: 1.5K
CLOSE FRONT
0.5
0.3
0.4
L3: 2.2K
L4: 0.8K
L5: 1.6K
OPEN FRONT
0.6
0.1
0.4
0.7
L6: 1.0K
L7: 2.0K
L8: 2.1K
L9: 1.1K

FIG.18

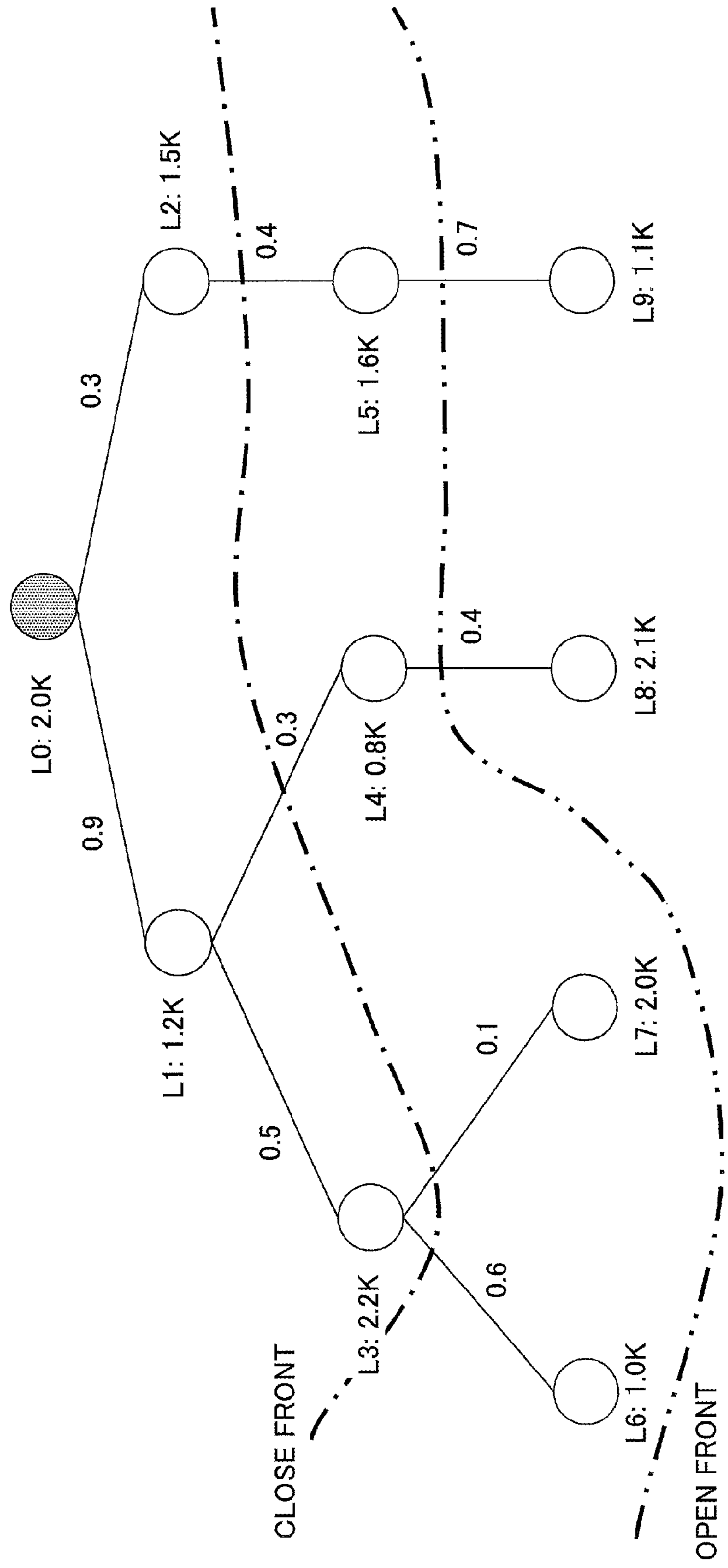

L0: 2.0K
0.9
0.3
L1: 1.2K
L2: 1.5K
0.5
0.3
0.4
L3: 2.2K
L4: 0.8K
L5: 1.6K
0.6
0.1
0.4
0.7
L6: 1.0K
L7: 2.0K
L8: 2.1K
L9: 1.1K
CLOSE FRONT
OPEN FRONT

FIG.19

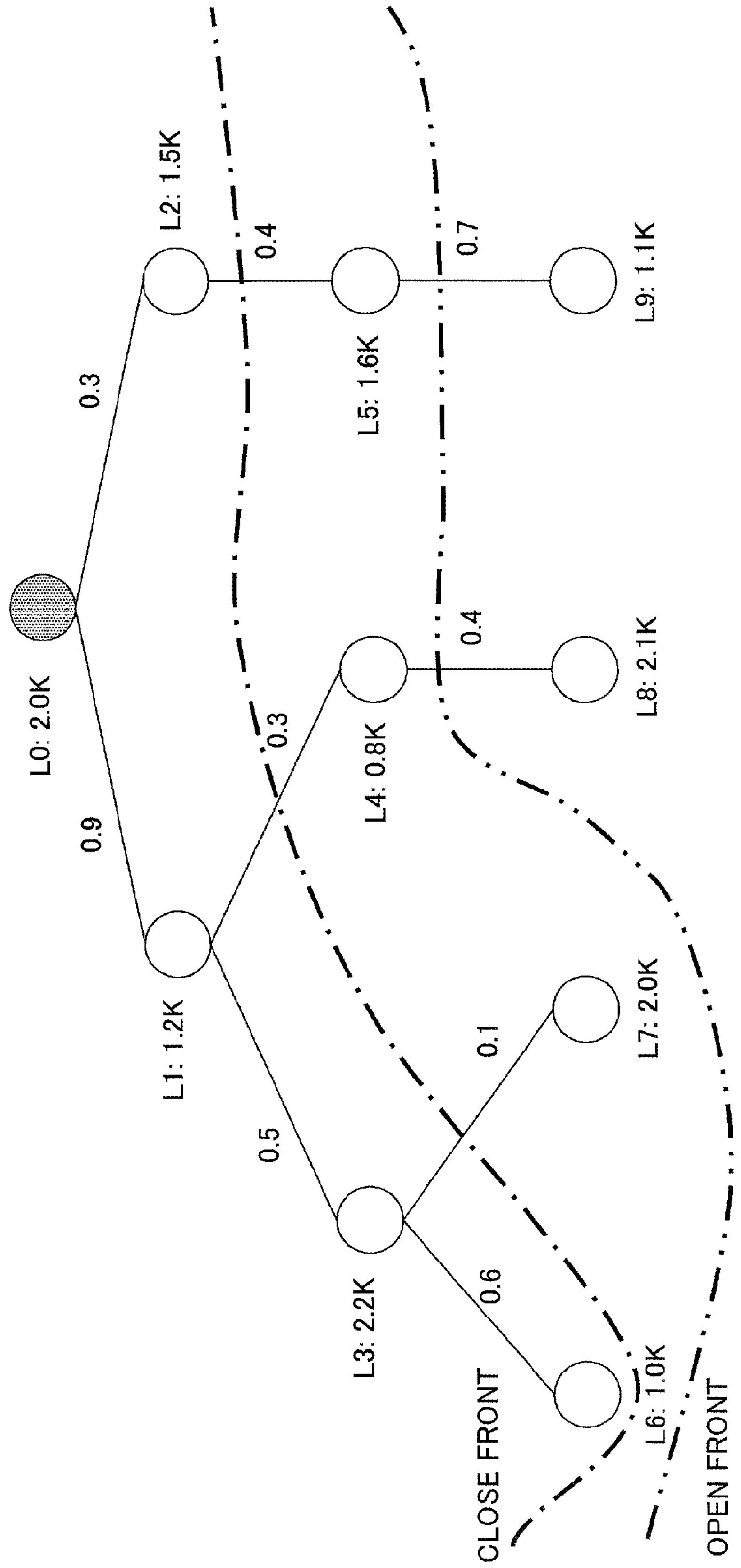

L0: 2.0K
0.3
0.9
L2: 1.5K
0.4
L5: 1.6K
0.7
L9: 1.1K
L1: 1.2K
0.3
L4: 0.8K
0.4
L8: 2.1K
0.5
L3: 2.2K
0.1
L7: 2.0K
0.6
L6: 1.0K
CLOSE FRONT
OPEN FRONT

FIG.20

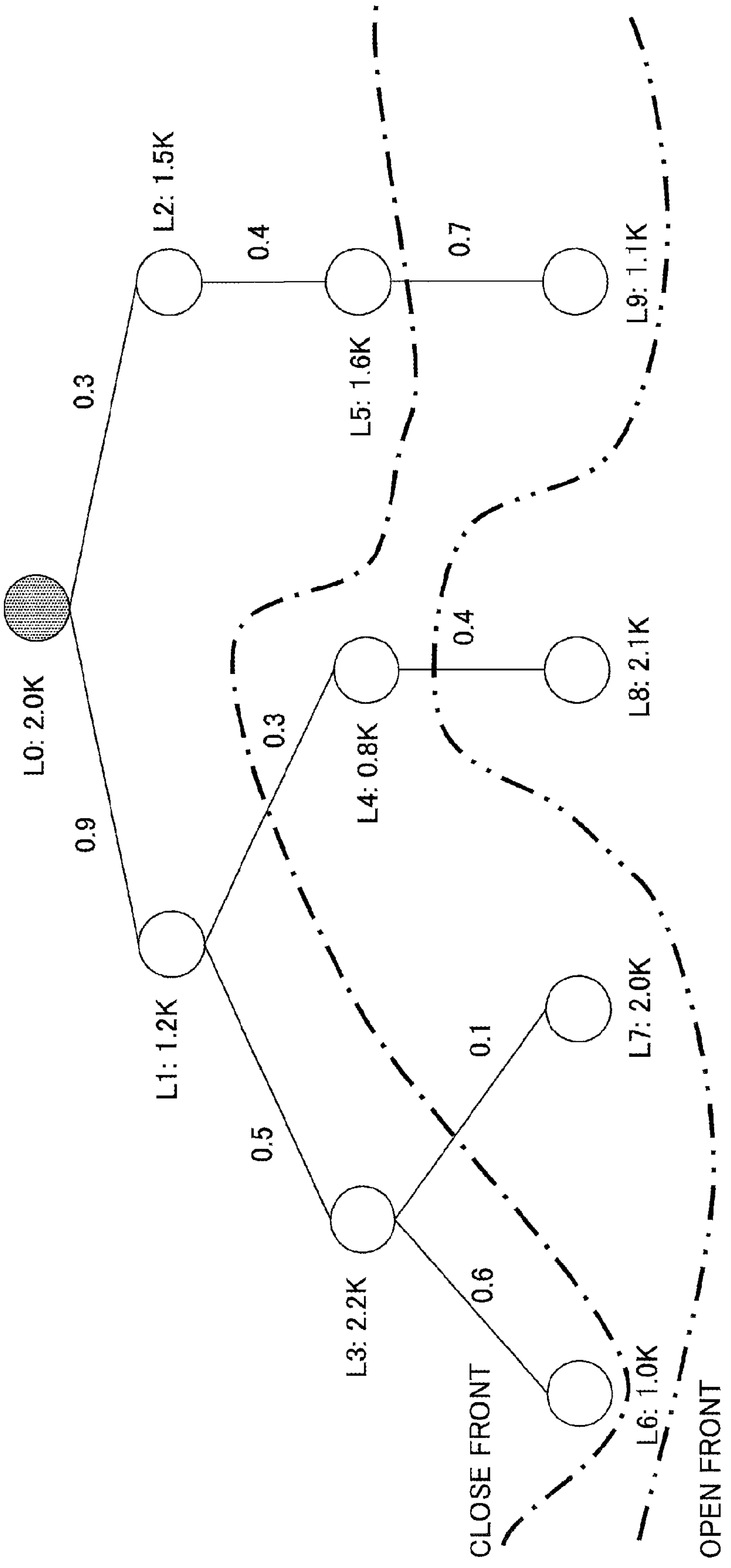

L0: 2.0K
L1: 1.2K
L2: 1.5K
L3: 2.2K
L4: 0.8K
L5: 1.6K
L6: 1.0K
L7: 2.0K
L8: 2.1K
L9: 1.1K
0.9
0.3
0.5
0.3
0.4
0.7
0.4
0.1
0.6
CLOSE FRONT
OPEN FRONT

FIG.21

200

LOCATION NUMBER	LOCATION NAME	THRESHOLD VALUE	CLOSE FRONT TAG	OBSERVABLE AP LIST																	
				MAC ADDRESS						MAC ADDRESS						MAC ADDRESS					
				MISSING PROBABILITY	OBSERVING PROBABILITY	OBSERVING PROBABILITY FOR EACH STRENGTH LEVEL				MISSING PROBABILITY	OBSERVING PROBABILITY	OBSERVING PROBABILITY FOR EACH STRENGTH LEVEL				MISSING PROBABILITY	OBSERVING PROBABILITY	OBSERVING PROBABILITY FOR EACH STRENGTH LEVEL			
						1	2	3	4			1	2	3	4			1	2	3	4
1	L1																				
2	L2																				
...																					

FIG.22

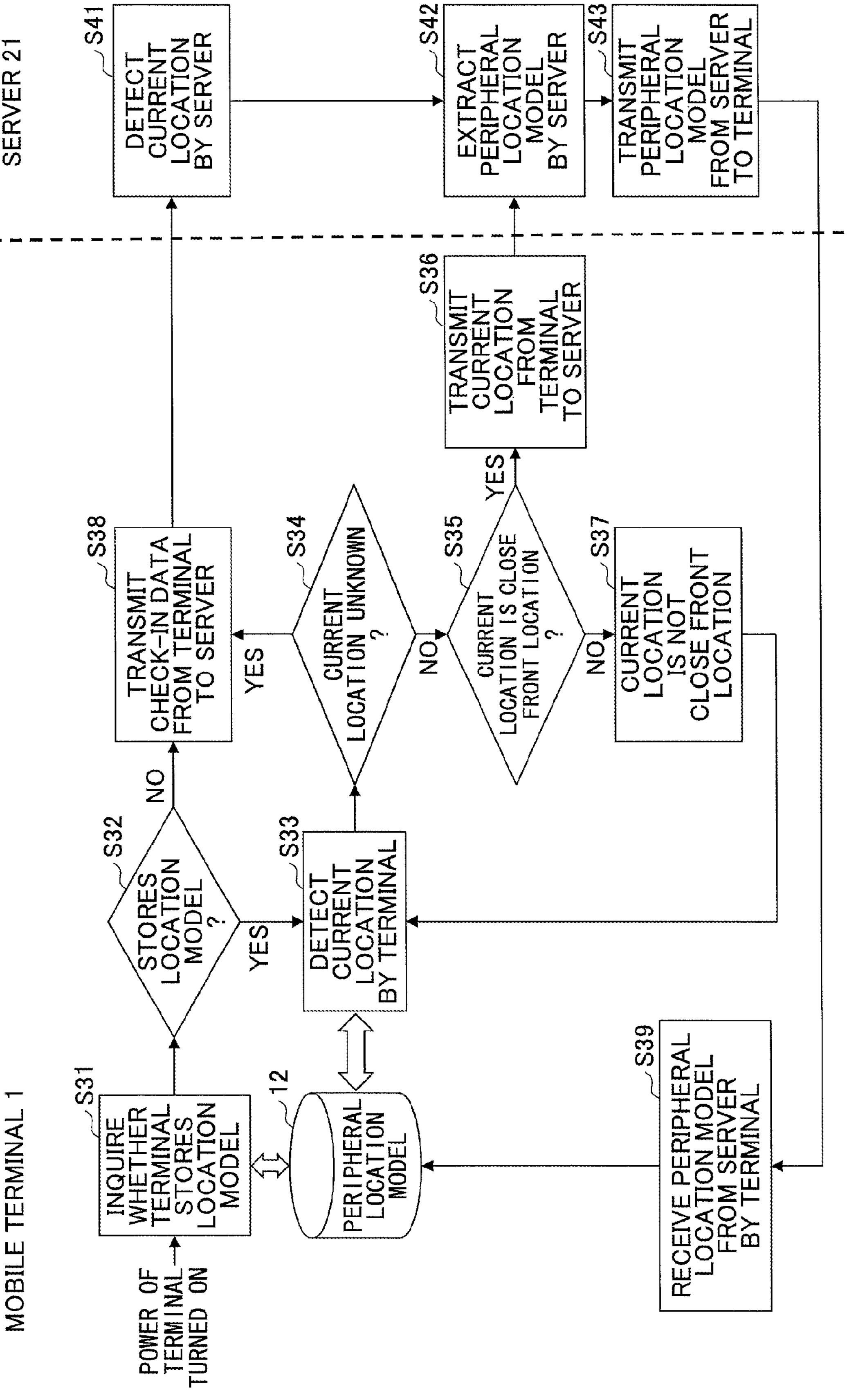

MOBILE TERMINAL 1
SERVER 21
POWER OF TERMINAL TURNED ON
S31
INQUIRE WHETHER TERMINAL STORES LOCATION MODEL
12
PERIPHERAL LOCATION MODEL
S32
STORES LOCATION MODEL ?
YES
NO
S33
DETECT CURRENT LOCATION BY TERMINAL
S38
TRANSMIT CHECK-IN DATA FROM TERMINAL TO SERVER
S34
CURRENT LOCATION UNKNOWN ?
YES
NO
S35
CURRENT LOCATION IS CLOSE FRONT LOCATION ?
YES
NO
S37
CURRENT LOCATION IS NOT CLOSE FRONT LOCATION
S36
TRANSMIT CURRENT LOCATION FROM TERMINAL TO SERVER
S41
DETECT CURRENT LOCATION BY SERVER
S42
EXTRACT PERIPHERAL LOCATION MODEL BY SERVER
S43
TRANSMIT PERIPHERAL LOCATION MODEL FROM SERVER TO TERMINAL
S39
RECEIVE PERIPHERAL LOCATION MODEL FROM SERVER BY TERMINAL

FIG.23

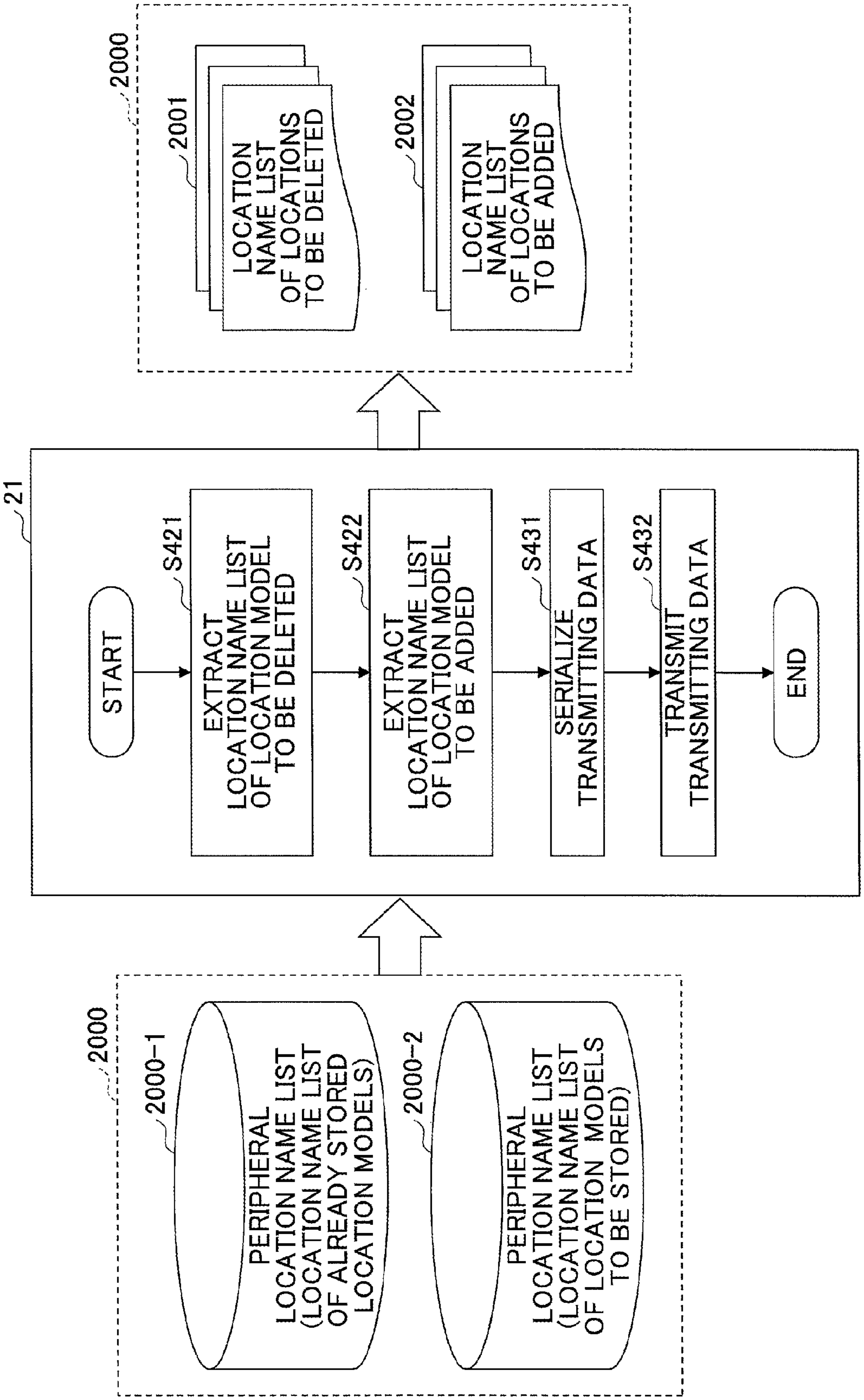
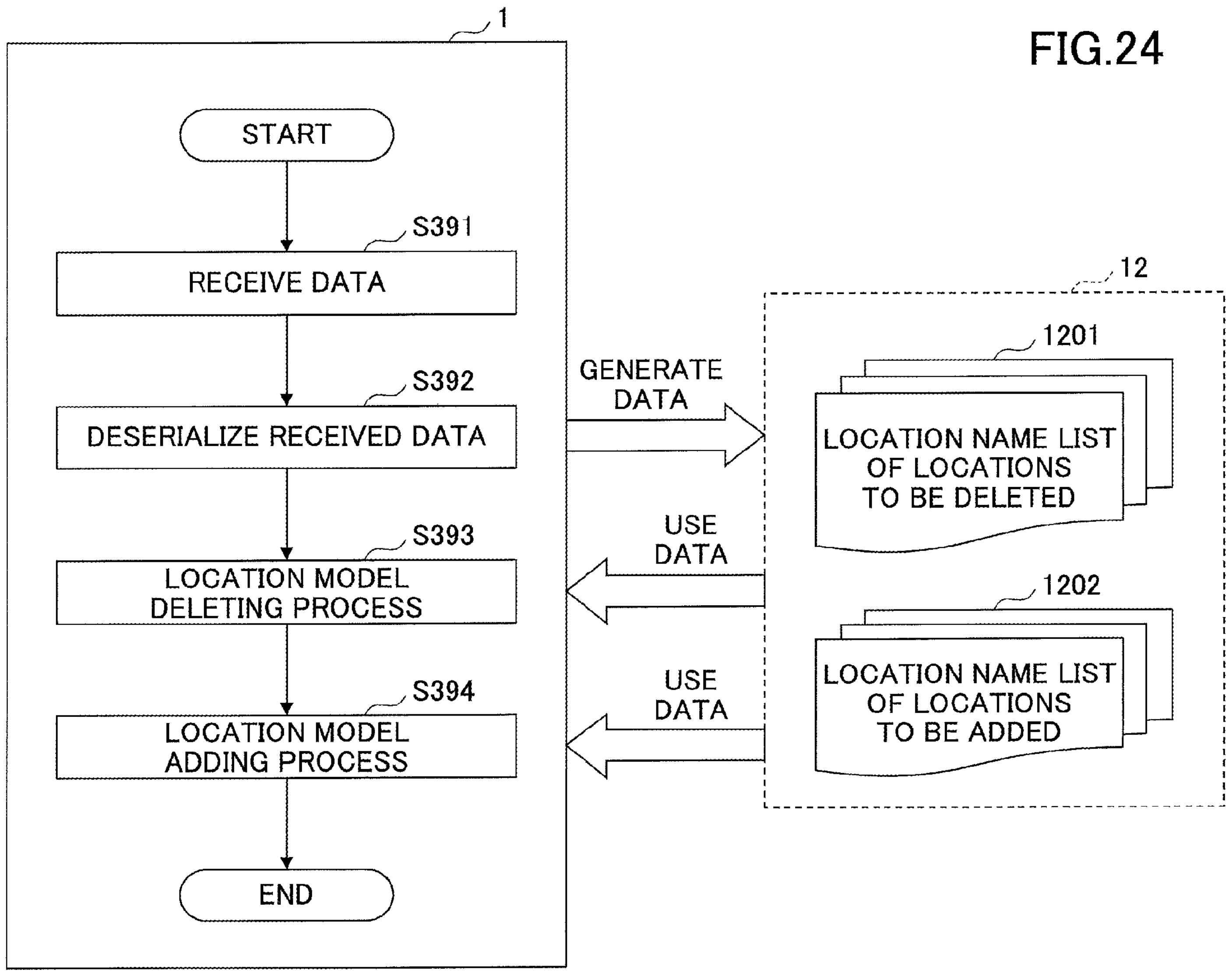

2000
2000-1
PERIPHERAL LOCATION NAME LIST (LOCATION NAME LIST OF ALREADY STORED LOCATION MODELS)
2000-2
PERIPHERAL LOCATION NAME LIST (LOCATION NAME LIST OF LOCATION MODELS TO BE STORED)
21
START
S421
EXTRACT LOCATION NAME LIST OF LOCATION MODEL TO BE DELETED
S422
EXTRACT LOCATION NAME LIST OF LOCATION MODEL TO BE ADDED
S431
SERIALIZE TRANSMITTING DATA
S432
TRANSMIT TRANSMITTING DATA
END
2000
2001
LOCATION NAME LIST OF LOCATIONS TO BE DELETED
2002
LOCATION NAME LIST OF LOCATIONS TO BE ADDED

FIG.24


1
START
S391
RECEIVE DATA
S392
DESERIALIZE RECEIVED DATA
S393
LOCATION MODEL DELETING PROCESS
S394
LOCATION MODEL ADDING PROCESS
END
GENERATE DATA
USE DATA
USE DATA
12
1201
LOCATION NAME LIST OF LOCATIONS TO BE DELETED
1202
LOCATION NAME LIST OF LOCATIONS TO BE ADDED

LOCATION MODEL UPDATING APPARATUS AND POSITION ESTIMATING METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2013-202018, filed on Sep. 27, 2013, the entire contents of which are incorporated herein by reference.

FIELD

The embodiments discussed herein are related to a location model updating apparatus, a position estimating method, and a computer-readable storage medium.

BACKGROUND

A position estimating technique has been proposed in which a mobile terminal such as a mobile phone, which is an example of a terminal apparatus, makes wireless communications with a plurality of base stations, and estimates a location of the mobile terminal by utilizing attenuation of received signal strengths depending on a distance to the mobile terminal from each of the plurality of base stations. For example, the base station may be an AP (Access Point) used in WiFi (Wireless Fidelity, registered trademark).

According to such a position estimating technique, the mobile terminal collects, in advance, IDs (Identifiers) of the plurality of base stations and RSSIs (Received Signal Strength Indicators) received at each location. From the IDs of the plurality of base stations and values of the RSSIs received at each location, an RSSI feature vector that is uniquely determined for each location is created, and a location model is created for each location using the RSSI feature vector. The location model may make a reference to a database indicating the location where the signals are received from the base stations, the base stations from which the signals are received by the mobile terminal at the location, and the RSSIs of the signals received by the mobile terminal at the location. When estimating the location, the RSSIs of the signals received by the mobile terminal from the base stations are collated with the location model, in order to estimate the location of the mobile terminal. Generally, the location model may be created by methods such as the k-NN (k-Nearest Neighbor algorithm) method, probability method based on probability distribution, non-parametric method, pattern matching method, or the like.

When the number of locations is large, the RSSI of the signal received from the base station by the mobile terminal needs to be collated with a large number of location models. A large storage capacity must be secured in order to store the large number of location models in the mobile terminal, because an amount of information of each location model is relatively later. However, the storage capacity of the mobile terminal is limited, and in some cases, a sufficiently large storage capacity cannot be secured to store the large number of location models. Hence, it is conceivable to simply decimate the large number of location models with which the RSSI of the signal received from the base station by the mobile terminal needs to be collated. But since it is impossible to know the location of the mobile terminal in advance, the position estimating accuracy deteriorates unless all of the location models are stored in the mobile terminal. On the other hand, although the position estimating accuracy can be maintained by securing the sufficiently large storage capacity to store all of the location models in the mobile terminal, a memory having the large storage capacity needs to be provided in the mobile terminal, and a cost of the mobile terminal increases due to the need to provide such a memory having the large storage capacity.

Conventionally, it is difficult to reduce the storage capacity for storing the location models, without sacrificing the position estimating accuracy.

Examples of the related art include Japanese Laid-Open Patent Publications No. 2012-145586 and No. 2013-053930.

SUMMARY

Embodiments may reduce a storage capacity for storing location models in a terminal apparatus, without sacrificing the position estimating accuracy.

According to one aspect of the present invention, a location model updating apparatus may include a storage unit, and a processor configured to generate attribute data in which an attribute of a location is represented by a location name and a data size of a location model, and an attribute between locations is represented by a similarity between the locations; extract a peripheral location by including each location from a current location of a terminal apparatus to a first front as a member of a definite peripheral location list, including each location from the first front to a second front as a member of a candidate peripheral location list, and updating each location that is a member of the definite peripheral location list and exists from the current location to the first front, and each location that is a member of the candidate peripheral location list and exists from the first front to the second front, using the current location of the terminal apparatus as a query; and transmit data of a peripheral location model of the peripheral location that is extracted, to the terminal apparatus, by including in the peripheral location model a flag identifying the peripheral location that is extracted as a location up to the first front.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram illustrating an example of a configuration of a mobile terminal in one embodiment;

FIG. **2** is a diagram for explaining an example of a relationship of locations where a plurality of APs and a mobile terminal may exist;

FIG. **3** is a flow chart for explaining an example of a position estimating process of the mobile terminal;

FIG. **4** is a diagram illustrating an example of a data structure of an all-region AP information list;

FIG. **5** is a diagram illustrating an example of a data structure of a location model;

FIG. **6** is a diagram for explaining an example of an operation of a position estimating system in one embodiment;

FIG. **7** is a diagram for explaining an example of the location model;

FIG. **8** is a block diagram illustrating in more detail a configuration of an example of the position estimating system applied with a technique conceived by the present inventor;

FIG. **9** is a diagram for explaining an example of a place graph;

FIG. **10** is a diagram illustrating an example of a distribution of first likelihood difference values;

FIG. **11** is a diagram illustrating an example of a distribution of second likelihood difference values;

FIG. **12** is a diagram illustrating an example of a distribution distance between the first and second likelihood differences;

FIG. **13** is a diagram for explaining an example of a similarity matrix;

FIG. **14** is a flow chart for explaining an example of an updating process to update a definite peripheral location list and a candidate peripheral location list;

FIG. **15** is a flow chart for explaining in more detail an example of a peripheral location extracting process;

FIG. **16** is a diagram illustrating an example of a place graph used by the peripheral location extracting process;

FIG. **17** is a diagram illustrating an example of the place graph used by the peripheral location extracting process;

FIG. **18** is a diagram illustrating an example of the place graph used by the peripheral location extracting process;

FIG. **19** is a diagram illustrating an example of the place graph used by the peripheral location extracting process;

FIG. **20** is a diagram illustrating an example of the place graph used by the peripheral location extracting process;

FIG. **21** is a diagram illustrating another example of the data structure of the location model;

FIG. **22** is a flow chart for generally explaining processes at a server and the mobile terminal;

FIG. **23** is a diagram for explaining in more detail a part of the process at the server; and

FIG. **24** is a diagram for explaining in more detail a part of the process at the mobile terminal.

DESCRIPTION OF EMBODIMENTS

Preferred embodiments of the present invention will be described with reference to the accompanying drawings.

A description will now be given of the location model updating apparatus, the position estimating method, and the computer-readable storage medium in each embodiment according to the present invention.

In one embodiment, the location model updating apparatus may generate attribute data in which an attribute of a location is represented by a location name and a data size of a location model, and an attribute between locations is represented by a similarity between the locations. The location model updating apparatus may extract a peripheral location by including each location from a current location of a terminal apparatus to a first front as a member of a definite peripheral location list, including each location from the first front to a second front as a member of a candidate peripheral location list, and updating each location that is a member of the definite peripheral location list and exists from the current location to the first front, and each location that is a member of the candidate peripheral location list and exists from the first front to the second front, using the current location of the terminal apparatus as a query. The location model updating apparatus may transmit data of a peripheral location model of the peripheral location that is extracted, to the terminal apparatus, by including in the peripheral location model a flag identifying the peripheral location that is extracted as a location up to the first front.

For example, the data of the peripheral location model, received by the terminal apparatus from the location model updating apparatus, may be difference data between the location model stored in the terminal apparatus and the peripheral location model extracted in the location model updating apparatus.

FIG. **1** is a block diagram illustrating an example of a configuration of a mobile terminal in one embodiment. A mobile terminal **1** illustrated in FIG. **1** is an example of a terminal apparatus provided with a communication function, which may be formed by a mobile phone such as a smart phone, for example. The mobile terminal **1** includes a CPU (Central Processing Unit) **11**, a storage unit **12**, an input device **13**, a display unit **14**, and a communication unit **15** that are connected via a bus **16**. The mobile terminal **1** is not limited to the connection using the bus **16**.

The CPU **11** is an example of a computer or processor. The CPU **11** controls the entire mobile terminal **1**, and executes a position estimating process or the like to be described later, by executing one or more programs. The storage unit **12** stores one or more programs to be executed by the CPU **11**, data to be used in computations performed by the CPU **11**, or the like. The storage unit **12** may be formed by a non-transitory computer-readable storage medium. The non-transitory computer-readable storage medium may be formed by a semiconductor memory device. In a case in which the non-transitory computer-readable storage medium is formed by a recording medium such as a magnetic recording medium, an optical recording medium, a magneto-optical recording medium, or the like, the storage unit **12** may be formed by a reader and writer (or read and write unit) that reads information from and writes information to the recording medium that is loaded into the reader and writer.

The input device **13** may be formed by a keyboard or the like, and is operated by a user when inputting commands, data, or the like to the mobile terminal **1**, for example. The display unit **14** may be formed by an LCD (Liquid Crystal Display) or the like, for example, and displays guidances, messages, or the like. The input device **13** and the display unit **14** may be formed integrally by a touchscreen panel, for example. The communication unit **15** has a wireless communication function capable of making wireless communication with an external apparatus (not illustrated), and has a known configuration including a receiver, a transmitter, an antenna, or the like. In this example, the communication unit **15** is communicable with an AP (Access Point) that uses WiFi, for example. The AP is an example of a base station.

FIG. **2** is a diagram for explaining an example of a relationship of locations where a plurality of APs and the mobile terminal may exist. In the example illustrated in FIG. **2**, a plurality of APs, namely, APs AP1 through AP5, cover locations having location names L1 and L2, and the mobile terminal **1** carried by the user exists within the location having the location name L1. The RSSI at the mobile terminal **1** is RSSI-1 from the AP AP1, RSSI-1 from the AP AP2, RSSI-3 from the AP AP3, RSSI-4 from the AP AP4, and RSSI-5 from the AP AP5.

FIG. **3** is a flow chart for explaining an example of a position estimating process of the mobile terminal. The position estimating process illustrated in FIG. **3** may be executed by the CPU **11**. In FIG. **3**, the CPU **11** in step S**1** scans WiFi data from each of the APs AP1 through AP5 to obtain WiFi scan data, acquires a MAC (Media Access Control) address of each of the APs AP1 through AP5 and the RSSIs from the WiFi scan data, and creates RSSI feature vectors. The CPU **11** in step S**1** also refers to an all-region AP information list **100** stored in the storage unit **12**, and excludes unlearned APs not included in the all-region AP information list **100**.

FIG. **4** is a diagram illustrating an example of a data structure of the all-region AP information list. The all-region AP information list **100** illustrated in FIG. **4** includes, with respect to AP numbers 1, 2, . . . that are arbitrarily allocated to each of the APs, MAC addresses M1, M2, . . . of the APs, and an AP covering location list. The AP covering location list includes the location names L1, L2, L3, . . . of the locations.

As will be described below, the all-region AP information list **100** may be created based on the information acquired from the WiFi scan data. First, a blank all-region AP information list **100** is prepared. Thereafter, when the all-region AP information list **100** is searched and a check-in AP at a source of the WiFi scan data is new, the MAC address of the check-in AP is added to the all-region AP information list **100**. At the same time, the location name that is checked in is added to a covering location list of this check-in AP. In a case in which the check-in AP is already stored in the all-region AP information list **100**, the covering location list of this check-in AP is searched, and a check-in location name is added to the covering location list when the check-in location name is new.

In FIG. **3**, the CPU **11** in step **S2** refers to the all-region AP information list **100** to create a candidate location list of all coverage locations of the searched APs, as candidate locations, and stores the created candidate location list in the storage unit **12**. The CPU **11** in step **S2** also executes the following processes with respect to each AP APi. First, the CPU **11** performs a process to extract a coverage location list of each AP APi by referring to the all-region AP information list **100**. Next, the CPU **11** performs a process to add all members (that is, all locations) of the coverage location list of each AP APi to the candidate location list, but this process is skipped when the member (that is, location) is already added to the candidate location list. Next, the CPU **11** makes a judgment to determine whether the process with respect to all APs APi is completed. When the judgment result is NO, the process of the CPU **11** returns to the process to extract the coverage location list, and the process advances to step **S3** illustrated in FIG. **3** when the judgment result is YES.

In FIG. **3**, the CPU **11** in step S3 computes a first stage observing probability of the AP that is the source of the WiFi scan data, with respect to each member (that is, each location) of the candidate location list. FIG. **5** is a diagram illustrating an example of a data structure of a location model. A location model **200** illustrated in FIG. **5** includes a location number, a location name, a threshold value of a second stage observing probability to be used within the location, and an observable AP list. The observable AP list includes a missing probability, observing probability, an observing probability for each strength level of the RSSI for a case in which the AP is observed, or the like, with respect to the MAC address. FIG. **5** illustrates a case in which the number of strength levels of the RSSI for the case in which the AP is observed is four (4), and a length of the observable AP list is three (3), for example. The location model **200** is stored in the storage unit **12**, for example. Because the observable AP list includes a probability information part of the location model **200**, the observable AP list in FIG. **3** is illustrated as a “location model (probability information)”. On the other hand, because parts other than the observable AP list includes a threshold value information part of the second stage observing probability to be used at each location of the location model **200**, the parts other than the observable AP list in FIG. **3** is illustrated as a “location model (threshold value information)”.

The CPU **11** in step S3 performs the following processes for each AP APi, with respect to each candidate location. First, the CPU **11** searches the observable AP list of the candidate location in the location model **200** illustrated in FIG. **5**, and acquires an observing probability that is learned in advance when the AP APi is included in the observable AP list. On the other hand, when the AP APi is not included in the observable AP list, the CPU **11** sets a relatively small constant that is set in advance, for example, as the observing probability of the AP APi. Next, the CPU **11** accumulates the observing probability of the AP APi to a product of the observing probability stored in the storage unit **12**, and the CPU **11** makes a judgment to determine whether the process with respect to all APs APi is completed. When the judgment result is NO, the process of the CPU **11** returns to the process with respect to each AP APi, and when the judgment result is YES, the CPU **11** extracts the observable AP list of the candidate location of the location model **200** illustrated in FIG. **5**.

Next, the CPU **11** performs the following processes with respect to each observable AP. First, the CPU **11** searches the WiFi scan data (AP1(MAC, RSSI, . . .)) to judge whether the observable AP is missing. When the MAC address of the observable AP is not included in the WiFi scan data, the CPU **11** judges that there is no missing observable AP, and the CPU **11** repeats the judgment to determine whether the observable AP is missing. On the other hand, when the CPU **11** judges that there is a missing observable AP, the CPU **11** extracts the missing probability of the missing observable AP from the location model **200**, and the CPU **11** accumulates the missing probability to a product of the missing probability stored in the storage unit **12**. When the process with respect to all observable APs is completed, the CPU **11** computes a product of the product of the observing probability and the product of the missing probability stored in the storage unit **12**. The CPU **11** defines the computed product as the first stage observing probability of the candidate location, and the computed product is paired with the candidate location by the CPU **11** and stored in the storage unit **12**. When the process with respect to all candidate locations is completed, the process of the CPU **11** advances to step S4 illustrated in FIG. **3**.

In FIG. **3**, the CPU **11** in step **S4** discards the candidate locations having a low or low order first stage observing probability, in order to narrow the candidate locations. The CPU **11** in step **S5** computes the second stage observing probability based on the RSSI feature vector, with respect to the narrowed candidate locations. A second stage observing probability computing process performs the computation with respect to the candidate location list that is narrowed in step **S4** by the first stage observing probability computed in step **S3**.

The CPU **11** in step **S5** performs the following processes for each AP APi, with respect to each candidate location. First, the CPU **11** refers to the location model **200**, and when the MAC address of the AP APi is included in the observable AP list of the candidate location, the CPU **11** computes the strength level from the RSSI of the AP APi, and acquires from the location model **200** the observing probability for each strength level of the RSSI for the case in which the AP APi is observed. On the other hand, when the MAC address of the AP APi is not included in the observable AP list of the candidate location, the CPU **11** sets a relatively small constant that is set in advance, for example, as the observing probability for each strength level of the RSSI for the case in which the AP APi is observed. Next, the CPU **11** accumulates the observing probability for each strength level of the RSSI for the case in which the AP APi is observed to a product of the observing probability for each strength level stored in the storage unit **12**, and the CPU **11** makes a judgment to determine whether the process with respect to all APs APi is completed. When the judgment result is NO, the process of the CPU **11** returns to the process with respect to each AP APi, and when the judgment result is YES, the CPU **11** computes a product of the product of the missing probability computed in step S3 and the product of the observing probability for each strength level, to store the computed product in the storage unit **12**. Then, the CPU **11** defines the computed product as the second stage observing probability, and the computed product is paired with the candidate location by the CPU **11** and stored in the storage unit **12**. When the process with respect to all candidate locations is completed, the process of the CPU **11** advances to step S6 illustrated in FIG. **3**.

In FIG. **3**, the CPU **11** in step S6 extracts (or selects) the candidate location having the largest second stage observing probability. The CPU **11** in step S7 refers to the location model **200** illustrated in FIG. **5**, and determines a final candidate location by making a judgment using a threshold value of the candidate location having the largest second stage observing probability. When the second stage observing probability is less than the threshold value, the CPU **11** judges that the mobile terminal **1** is not located at a final candidate location and the location of the mobile terminal **1** is unknown. On the other hand, when the second stage observing probability is greater than or equal to the threshold value, the CPU **11** judges that the mobile terminal **1** is located at the final candidate location. The CPU **11** in step S**8** outputs a judgment result indicating the location of the mobile terminal **1**, or indicating that the location of the mobile terminal **1** is unknown, and the position estimating process ends. The judgment result output in step S**8** may be output to application software or the like that provides services utilizing the position of the mobile terminal **1**, for example.

By executing the processes of steps S1 through S**5** corresponding to procedures of the position estimating method, the CPU **11** may function as a narrowing unit or means to narrow the candidate positions of the mobile terminal that are estimated from the signals received from the plurality of base stations, based on the missing data of the signal received from a certain base station. In addition, by executing the processes of steps S**6** and S7 corresponding to procedures of the position estimating method, the CPU **11** may function as an estimating unit or means to estimate the position of the mobile terminal from the narrowed candidate positions, based on the observing probability of the strength of the signals received.

Next, a description will be given of an example of a position estimating system in one embodiment, by referring to FIG. **6**. FIG. **6** is a diagram for explaining an example of an operation of the position estimating system in one embodiment. A position estimating system **20** illustrated in FIG. **6** includes a mobile terminal **1**, and a server **21** communicable with the mobile terminal **1** by wireless communication. The server **21** has a function to learn (hereinafter also referred to as "update") the location model **200**, using data (hereinafter also referred to as "check-in data") checked in from the mobile terminal **1**. The mobile terminal **1** performs the position estimating process based on RSSI feature vectors that are newly observed, using the location model **200** downloaded from the server **21**. The server **21** has a known configuration including a processor and a storage unit, and may have a hardware configuration similar to that of the mobile terminal **1** illustrated in FIG. **1**, for example. For this reason, illustration and description of the hardware configuration of the server **21** will be omitted. In this example, the server **21** functions as an example of a location data updating apparatus.

In step ST**1** illustrated in FIG. **6**, the processor (for example, CPU **11**) of the mobile terminal **1** acquires the check-in data by acquiring the MAC address and the RSSI of each AP from the WiFi scan data. In step ST**2**, the processor of the mobile terminal **1** transmits the check-in data to the server **21**.

In step ST**21**, the processor (corresponding to CPU **11** illustrated in FIG. **1**, for example) of the server **21** receives the check-in data from the mobile terminal **1**, and stores the check-in data in a check-in data file **300** within the storage unit (corresponding to the storage unit **12** illustrated in FIG. **1**, for example) of the server **21**. In step ST**22**, the processor of the server **21** reads the check-in data file **300** from the storage unit of the server **21**, and executes the updating process to update the location model **200**.

The updating process to update the location model **200** may include updating the probability information part of the location model **200**, updating the threshold value information part of the location model, or the like. Updating the probability information part updates the location model (probability information) corresponding to the probability information part of the location model **200**, using the check-in data. Thereafter, when computing the second stage observing probability, the process of a second stage of the location estimation is performed with respect to the check-in data, based on the location model (probability information). The second stage observing probability and the location name of the check-in location, obtained by the process of the second stage of the location estimation, are used to compute the threshold value of the second stage observing probability, that is, the threshold value at each check-in location, in order to update the location model (threshold value information) corresponding to the threshold value information part of the location model **200**. The updating process to update the location model **200** is completed after the probability information part and the threshold value information part of the location model **200** are updated.

In step ST**23**, the processor of the server **21** generates a file (hereinafter also referred to as a "location model file") **200**A of the updated location model **200**, and stores the location model file **200**A in the storage unit of the server **21**. In step ST**24**, the processor of the server **21** reads the location model file **200**A from the storage unit of the server **21**, and transmits the location model file **200**A to the mobile terminal **1**.

In step ST**3**, the process of the mobile terminal **1** receives the location model file **200**A from the server **21**, and stores the location model file **200**A in the storage unit **12** of the mobile terminal **1**. In other words, the mobile terminal **1** stores the location model file **200**A in the storage unit **12** and updates the location model **200** every time a new location model file **200**A is generated in the server **21**. In step ST**4**, the processor of the mobile terminal **1** reads the location model file **200**A from the storage unit **12**, to perform the position estimating process based on the RSSI feature vectors of the check-in data, using the location model **200**, and outputs a judgment result on the location of the mobile terminal **1**.

FIG. **7** is a diagram for explaining an example of the location model. FIG. **7** illustrates the AP observing and missing probabilities, and the observing probability for each RSSI level. In HTG1 of FIG. **7**, (a) illustrates missing and observing histograms for an example in which, amongst 22 learning samples (check-in data) collected at a location having a location name L1, 5 samples are the samples missing observation of the AP AP1, and 17 samples are the samples of observation of the AP AP1. In this case, at the location having the location name L1, the missing probability of the AP AP1 is 5/22=0.227, and the observing probability of the AP AP1 is 17/22=0.773. In addition, in HTG1 of FIG. **7**, (b) illustrates an RSSI histogram in which, amongst 17 samples of the AP AP1 observed, 4 samples have the RSSI level 0, 6 samples have the RSSI level 1, 5 samples have the RSSI level 2, and 2 samples have the RSSI level 3. Accordingly, when the AP AP1 is observed at the location having the location name L1, the observing probability for the RSSI levels 0, 1, 2, and 3 are 4/17=0.235, 6/17=0.353, 5/17=0.294, and 2/17=0.118, respectively. Similarly, in HTG1 of FIG. **7**, (c) illustrates missing and observing histograms for an example in which, at the location having the location name L1, the missing probability of the AP AP2 is 2/22=0.091, and the observing probability of the AP AP2 is 20/22=0.909. Further, in HTG1 of FIG. **7**, (d) illustrates an RSSI histogram in which, when the AP AP2 is observed at the location having the location name L1, the observing probability for the RSSI levels 1, 2, 3, 4, and 5 are 2/20=0.100, 5/20=0.250, 2/20=0.100, 8/20=0.400, and 3/20=0.150, respectively.

In HTG2 of FIG. **7**, (a) illustrates missing and observing histograms for an example in which, amongst 20 learning samples (check-in data) collected at a location having a location name L2, 2 samples are the samples missing observation of the AP AP1, and 18 samples are the samples of observation of the AP AP1. In this case, at the location having the location name L2, the missing probability of the AP AP1 is 2/20=0.100, and the observing probability of the AP AP1 is 18/20=0.900. In addition, in HTG2 of FIG. **7**, (b) illustrates an RSSI histogram in which, amongst 18 samples of the AP AP1 observed, 1 sample has the RSSI level 1, 2 samples have the RSSI level 2, 3 samples have the RSSI level 3, 5 samples have the RSSI level 4, and 7 samples have the RSSI level 5. Similarly, in HTG2 of FIG. **7**, (c) illustrates missing and observing histograms for an example in which, at the location having the location name L2, the missing probability of the AP AP2 is 5/20=0.250, and the observing probability of the AP AP2 is 15/20=0.750. Further, in HTG2 of FIG. **7**, (d) illustrates an RSSI histogram in which, when the AP AP2 is observed at the location having the location name L2, the observing probability for the RSSI levels 0, 1, 2, 3, 4, and 5 are 4/15=0.267, 2/15=0.133, 3/15=0.200, 3/15=0.200, 2/15=0.133, and 1/15=0.067, respectively.

In HTG1 and HTG2 of FIG. **7**, the ordinates in (a) and (c) indicate the missing frequency and the observing frequency of the data observation, and the abscissas in (a) and (c) indicate the observation missing state or the observing state of the APs AP1 and AP2, respectively. In addition, in HTG1 and HTG2 of FIG. **7**, the ordinates in (b) and (d) indicate the observing frequency, and the abscissas in (b) and (d) indicate the RSSI level of the APs AP1 and AP2, respectively.

The likelihood of the candidate position can be computed from [Likelihood]=[Probability of Observing RSSI Level]× [Probability of Missing Observation of AP]. For example, in a case in which the RSSI obtained by scanning the AP AP1 has the RSSI level 1, the likelihood of the location having the location name L1 is [Probability of Observing RSSI Level 1 of AP AP1]×[Probability of Missing observation of AP AP2]=[6/17]×[2/22]=0.032. In addition, in a case in which the RSSI obtained by scanning the AP AP1 has the RSSI level 1 and the RSSI obtained by scanning the AP AP2 has the RSSI level 4, for example, the likelihood of the location having the location name L1 can be computed from [Probability of Observing RSSI Level 1 of AP AP1]×[Probability of Observing RSSI level 4 of AP AP2]=[6/17]×[8/20]=0.141.

An operator of the position estimating system may create in advance an initial location model based on RSSI samples collected from a predetermined number of locations. In this case, the position estimating accuracy can be improved by updating the initial location model based on the samples from the mobile terminal, at the time of updating the location model or during the position detection.

When the number of locations is large, the amount of information of the location model, that is, the data size, becomes large. However, when the number of location models to be collated with the RSSI of the signal received from the base station by the mobile terminal is simply decimated, the position estimating accuracy deteriorates since it is impossible to know the location of the mobile terminal in advance. The deterioration of the position estimating accuracy caused by the decimation of the number of location models to be collated occurs because the location model does not include a spatial relationship between the adjacent locations, and it is difficult to appropriately extract the location models to be collated at a current location of the mobile terminal from the large number of location models. Hence, the present inventor conceived a technique to reduce a storage capacity for storing the location models in the mobile terminal (or terminal apparatus), without sacrificing the position estimating accuracy, by obtaining the spatial relationship between the adjacent locations in a relatively simple manner and by extracting the location models to be used for the collation at the current location of the mobile terminal based on the spatial relationship.

Generally, the spatial relationship between the adjacent locations is unknown. However, in an environment of a general system in which the APs are arranged, it may be regarded that distributions of the RSSIs are similar between the adjacent locations. For example, between two mutually adjacent locations, the mobile terminal receives the signals from approximately the same APs, and thus, distributions of the RSSIs are similar. On the other hand, between two locations that are distant from each other, the mobile terminal receives the signals from different APs, and thus, the distributions of the RSSIs are different. Hence, by effectively utilizing these features, the spatial relationship between the adjacent locations is obtained from an observing state and an observation missing state of the signals from the APs, and the RSSI of the signals, at each of the adjacent locations.

More particularly, a place graph is generated at the server, using the current location of the mobile terminal as a query. This place graph represents an attribute of the location, and similarities of features between the adjacent locations, where the features include features related to frequencies of the observing state and the observation missing state of the signals from the APs, and features related to the RSSI of the signals. In other words, in the place graph, the attribute of the location is represented by the location name and the data size of the location model, and the attribute between the locations is represented by the similarities between the locations. The location models of peripheral locations to be used for the collation at the current location of the mobile terminal are extracted at the server based on the place graph, and the extracted location models are transmitted to the mobile terminal in order to update the location models stored within the mobile terminal to be used for the collation. Because only the location models to be used for the collation need to be stored and updated at the mobile terminal, the data size to be stored at the mobile terminal can be reduced even when the number of locations becomes large, and it is possible to reduce the storage capacity for storing the location models in the mobile terminal, without sacrificing the position estimating accuracy. In addition, because the data size to be stored at the mobile terminal can be reduced, it is unnecessary to provide a memory having a large storage capacity in the mobile terminal, to thereby enable reduction in the cost of the mobile terminal. Accordingly, even when the mobile terminal moves, it is possible to automatically update the peripheral location models to be used by the mobile terminal for the position estimation.

FIG. **8** is a block diagram illustrating in more detail a configuration of an example of the position estimating system applied with the technique conceived by the present inventor. In FIG. **8**, those parts that are the same as those corresponding parts in FIG. **6** are designated by the same reference numerals, and a description thereof will be omitted.

Step ST**23** illustrated in FIG. **8**, which is executed by the processor (corresponding to CPU **11** illustrated in FIG. **1**, for example) of the server **21**, includes steps ST**231** and ST**232**. In step ST**231**, the processor of the server **21** executes a place graph generating process to generate the place graph which will be described later, based on the check-in data and the location model. In step ST**232**, the processor of the server **21** executes a location model extracting process to extract the location models of the peripheral locations, located in the periphery of the current location of the mobile terminal **1**, based on the place graph read from the storage unit of the server **21**. The place graph may be stored in the location model file **200**A. In step ST**24**, the processor of the server **21** executes a transmitting process to transmit the location models of the peripheral locations, located in the periphery of the current location of the mobile terminal **1** and extracted by the location model extracting process of step ST**232**, to the mobile terminal **1**. On the other hand, in step ST**3**, the CPU **11** of the mobile terminal **1** receives the location models of the peripheral locations, located in the periphery of the current location of the mobile terminal **1** and extracted and transmitted by the server **21**. In step ST**301** included in step ST**3**, the CPU **11** of the mobile terminal **1** updates the location models stored in the storage unit **12**, based on the location models received from the server **21** in step ST**3**. In other words, every time the location model at the peripheral location located in the periphery of the current location of the mobile terminal **1** is extracted at the server **21**, the mobile terminal **1** updates the location model file **200**A stored in the storage unit **12** based on the location model downloaded from the server **21**. In step ST**4**, the CPU **11** of the mobile terminal **1** reads the updated location model file **200**A from the storage unit **12**, and performs a position estimating process based on the RSSI feature vector of the check-in data, using the updated location model **200**, in order to output a judgment result on the location of the mobile terminal **1**. In step ST**4**, the CPU **11** of the mobile terminal **1** collates the RSSI data obtained by the WiFi scan (step ST**1**) with the updated location model of the peripheral location, in order to detect the current location and estimate the current position of the mobile terminal **1**.

The processor of the server **21** may function as a generating unit or means to execute the place graph generating process of step ST**231**, and may function as an extracting unit or means to execute the location model extracting process of step ST**232**. In addition, the processor of the server **21** may function as a transmitting unit or means to execute the transmitting process of step ST**24**.

In the example illustrated in FIG. **8**, the sending of the check-in data from the mobile terminal (step ST**2**) may form a download request requesting the location model of the peripheral location with respect to the server **21**. In this case, when the server **21** accepts the download request, the server **21** executes, in addition to the processes of steps ST**21** and ST**22**, the place graph generating process and the location model extracting process of steps ST**231** and ST**232**, in order to extract the location model of the peripheral location in the periphery of the current location of the mobile terminal **1** and transmit the extracted location model to the mobile terminal **1** by the transmitting process of step ST**24**.

In step ST**301**, the CPU **11** of the mobile terminal **1** may transmit download requests, such as a location model update request that requests updating of the location model and a location model request that requests the location model of the peripheral location, with respect to the server **21**. In this case, when the processor of the server **21** accepts the download request in step ST**24**, the processor of the server **21** executes the place graph generating process and the location model extracting process in steps ST**231** and ST**232** of step ST**23**, and executes the transmitting process of step ST**24** in order to transmit the extracted location model to the mobile terminal **1**. Hence, in step ST**301**, the CPU **11** of the mobile terminal **1** can download the extracted location model of the peripheral location from the server **21**.

Next, a description will be given of the place graph generating process of step ST**231**, by referring to FIG. **9**. FIG. **9** is a diagram for explaining an example of the place graph. In FIG. **9**, a circular mark represents a location node of the place graph representing the locations. Each location name holds information such as the location name, the data size of histogram, or the like. For example, C0 represents data indicating the data size of the RSSI histogram at the location L1. The data C0, C1, . . . have values determined by the number of APs observed at the respective locations, and a unit of the data C0, C1, . . . is byte, for example. In addition, in FIG. **9**, a line connecting adjacent circular marks represents a link connecting the adjacent location nodes. The link represents a similarity, between RSSI distribution features including the observing state and the observation missing state of the signals from the APs and the RSSI of the signals at one of the adjacent locations, and RSSI distribution features including the observing state and the observation missing state of the signals from the APs and the RSSI of signals at the other of the adjacent locations, which is an example of the spatial relationship between the adjacent locations. For example, a value S01 of the link represents data indicating the similarity of the RSSI distribution features between the adjacent locations L0 and L1, and can be computed by a method which will be described later.

For example, the similarity of the RSSI distribution features between the locations L0 and L1 may be obtained by computing first and second likelihood differences as will be described hereinafter, and computing a distribution distance between the first and second likelihood differences.

Fist, the first likelihood difference may be computed as follows. That is, a difference q(a1)=p(a1|L1)−p(a1|L2), q(a2)=p(a2|L1)−p(a2|L2) between a likelihood p(a1|L1), p(a2|L1) of samples [a1(xx, . . .), L1], [a2(xx, . . .), L1] collected at the location L1 as data observed at the location L1, and a likelihood p(a1|L2), p(a2|L2) of the samples [a1 (xx, . . .), L1], [a2(xx, . . .), L1] collected at the location L1 as data observed at the location L2, is computed. FIG. **10** is a diagram illustrating an example of a distribution of first likelihood difference values, where the ordinate indicates the frequency in arbitrary units, and the abscissa indicates the first likelihood difference in arbitrary units. In a case in which the locations L1 and L2 are spatially close to each other, the respective likelihood values q are close to each other, and the first likelihood difference value is close to 0.0. On the other hand, in a case in which the locations L1 and L2 are spatially distant from each other, the likelihood value q observed at the location L1 is large compared to the likelihood value q observed at the location L2, and the first likelihood difference value becomes greater than 0.0.

Next, the second likelihood difference may be computed as follows. That is, a difference q(b1)=p(b1|L1)−p(b1|L2), q(b2)=p(b2|L1)−p(b2|L2) between a likelihood p(b1|L1), p(b2|L1) of samples [b1(xx, . . .), L2], [b2(xx, . . .), L2] collected at the location L2 as data observed at the location L1, and a likelihood p(b1|L2), p(b2|L2) of the samples [b1 (xx, . . .), L2], [b2(xx, . . .), L2] collected at the location L2 as data observed at the location L2, is computed. FIG. **11** is a diagram illustrating an example of a distribution of second likelihood difference values, where the ordinate indicates the frequency in arbitrary units, and the abscissa indicates the second likelihood difference in arbitrary units. In a case in which the locations L1 and L2 are spatially close to each other, the respective likelihood values q are close to each other, and the second likelihood difference value is close to 0.0. On the other hand, in a case in which the locations L1 and L2 are spatially distant from each other, the likelihood value q observed at the location L2 is large compared to the likelihood value q observed at the location L1, and the second likelihood difference value becomes greater than 0.0.

Next, a distribution distance between the first and second likelihood differences is computed. FIG. **12** is a diagram illustrating an example of the distribution distance between the first and second likelihood differences. In this example, the distribution distance between the first and second likelihood differences is represented by a likelihood difference variance ratio.

The likelihood difference variance includes a likelihood difference variance within the likelihood difference type, and a likelihood difference variance between the likelihood difference types. The likelihood difference variance within the likelihood difference type may be obtained from an average value of a variance of the first likelihood difference and a variance of the second likelihood difference, as represented by the following formula. In the following formulas, N_A denotes a number of samples collected at the location L1, N_B denotes a number of samples collected at the location L2, α_i denotes an ith sample collected at the location L1, b_j denotes a jth sample collected at the location L2, $q(\alpha_i)$ denotes the first likelihood difference computed from the sample α_i, $q(b_j)$ denotes the second likelihood difference computed from the sample b_j, m_α denotes an average value of the first likelihood difference, m_b denotes an average value of the second likelihood difference, and m denotes an average of the first likelihood difference and the second likelihood difference.

$$\sigma_w^2 = \frac{1}{N_A + N_B}\left(\sum_{i=0}^{N_A} (q(a_i) - m_a)^2 + \sum_{j=0}^{N_B} (q(b_j) - m_b)^2\right)$$

The likelihood difference variance between the likelihood difference types may be obtained from the average of the first likelihood difference and the average of the second likelihood difference, as represented by the following formula.

$$\alpha_b^2\{(1/(N_A+N_B)\}\{N_A(M_\alpha-m)^2+N_B(m_b-m)^2\}$$

Furthermore, a likelihood difference variance ratio may be obtained based on the following formula.

$$J_\rho=\sigma_b^2/\sigma_w^2$$

Accordingly, a similarity $S_{1,2}$ of the RSSI distribution features between the locations L0 and L1, represented by a value S01 of the link, may be obtained based on the following formula.

$$S_{1,2}=J\rho$$

The method of computing the likelihood is not limited to the computing method described above, and other known computing methods may be used. For example, instead of representing the RSSI distribution by a histogram, the RSSI distribution may be represented by a Gaussian distribution using the average variance.

FIG. **13** is a diagram for explaining an example of a similarity matrix. The place graph may be generated by computing the similarity matrix indicating a similarity between the locations, for example, representing the locations by the location nodes in the place graph, and linking the location nodes of the locations having similarities that are not zero (0). Because the similarity matrix is symmetrical as illustrated in FIG. **13**, it is sufficient to compute only the similarities (that is, the values of the links) in an upper right half or a lower left half with respect to a diagonal line extending from the upper left to the lower right of the similarity matrix. However, in a case in which no AP is shared between the two locations, the similarity is not computed, and instead, a zero (0) entry is made into a corresponding cell of the similarity matrix. As a result, it is possible to generate the place graph illustrated in FIG. **9**, for example.

The place graph may be a graph, a table, a tree, or the like representing the features of the locations and the similarities of the locations. The place graph is not limited to a graph, as long as the place graph includes attribute data in which the attribute of the location is represented by the location name and the data size of the location model, and the attribute between the locations is represented by the similarity between the locations.

Next, a description will be given of the location model extracting process of step ST**232**, by referring to FIGS. **14** and **15**. FIG. **14** is a flow chart for explaining an example of an updating process to update a definite peripheral location list and a candidate peripheral location list.

In step S**21** illustrated in FIG. **15**, the processor of the server **21** prepares a definite peripheral location list and a candidate peripheral location list, and initializes these lists that are stored in the storage unit of the server **21**, for example. The definite peripheral location list stores, as definite peripheral locations, the current location and the locations linked to the current location. In addition, the candidate peripheral location list stores, as candidate peripheral locations, indefinite locations linked to the definite peripheral locations. In step S**22**, the processor of the server **21** updates the definite peripheral location list. The updating of the definite peripheral location list includes extracting, from the candidate peripheral location list, a location having a highest similarity to the definite peripheral location, and storing, as the definite peripheral location, the location having the highest similarity in the definite peripheral location list.

In step S**23**, the processor of the server **21** judges whether a total of the model sizes of the location models of the definite peripheral locations exceeds a limit value, and the process advances to step S**24** when the judgment result is NO, and the process advances to step S**25** when the judgment result is YES. In step S**24**, the processor of the server **21** updates the candidate peripheral location list. The updating of the candidate peripheral location list includes storing, as the candidate peripheral location, the location (or candidate location) that is not stored in both the candidate peripheral location list and the definite peripheral location list at a link destination of the peripheral location that currently became definite. Accordingly, the updating of the definite peripheral location list and the updating of the candidate peripheral location list are repeated until the total of the model sizes of the location models of the definite peripheral locations reaches the limit value. In step S**25**, the processor of the server **21** reads the location model of the definite location from the storage unit of the server **21**.

FIG. **15** is a flow chart for explaining in more detail an example of a peripheral location extracting process. In step S**31** illustrated in FIG. **15**, the processor of the server **21** performs an initializing process. This initializing process clears the definite peripheral location list that stores the definite locations, clears the candidate peripheral location list that stores the candidate locations, and sets a total data size of the location models at the peripheral locations (hereinafter also referred to as "peripheral location models") to zero (0).

In step S**32**, the processor of the server **21** performs a close process, which is an example of a first process. This close process adds to the definite peripheral location list a location node of the current location of the mobile terminal (hereinafter also referred to as a "current location node"), and location nodes linked to the current location node. In step S**33**, the processor of the server **21** obtains the data sizes of the location models in the definite peripheral location list, and sets (or accumulates) the obtained data sizes to the total data size. In step S**34**, the processor of the server **21** performs an open process, which is an example of a second process. This open process adds to the candidate peripheral location list location nodes that are linked to the definite peripheral location list and are not stored in the candidate peripheral location link.

In step S**35**, the processor of the server **21** selects, from the candidate peripheral location list, a location node having a largest link value (that is, a highest similarity) with respect to a parent location node. In step S**36**, the processor of the server **21** estimates an estimated value of the total data size, by adding the data size of the location node selected in step S**35** to the data sizes of the location models in the definite peripheral location list. In step S**37**, the processor of the server **21** judges whether the estimated value of the total data size estimated in step S**36** is greater than or equal to the limit value, and the process advances to step S**40** when the judgment result is YES, and the process advances to step S**38** when the judgment result is NO. The limit value may be set according to the storage capacity (or memory size) of the storage unit at each of the mobile terminal **1** and the server **21**.

In step S**38**, the processor of the server **21** performs a close process. This close process adds the selected location node to the definite peripheral location list, in order to make definite the estimated total data size. In step S**39**, the processor of the server **21** adds to the candidate peripheral location list the location node that is linked to the location node selected by the close process and is not subjected to the open process nor the close process, and the process returns to step S**35**. In step S**40**, the processor of the server **21** extracts members (that is, locations) of the definite peripheral location list, and reads from the storage unit of the server **21** and prepares the peripheral location models to be transmitted to the mobile terminal **1**.

FIGS. **16** through **20** are diagrams illustrating examples of the place graph used by the peripheral location extracting process. In FIGS. **16** through **20**, those parts that are the same are designated by the same reference numerals.

FIG. **16** illustrates an example of the place graph for a case in which the peripheral locations of the current location are extracted. In this example, the location L0 is the current location, a data size C0 of the location model at the location L0 is 2.0K (K denotes "kilobytes"), a similarity S01 between the locations L0 and L1 is 0.9, the data size of the location model at the location L1 is 1.2K, a similarity between the locations L0 and L2 is 0.3, a data size C2 of the location model at the location L2 is 1.5K, and a similarity S**25** between the locations L2 and L5 is 0.4. Other values are as illustrated in FIG. **16**.

FIG. **17** illustrates a state after processes of steps S31 through S34 illustrated in FIG. **15** are performed with respect to the place graph illustrated in FIG. **16**. In FIG. **17**, a close front is indicated by a one-dot chain line, and an open front is indicated by a two-dot chain line. Each location from the current location L0 to the close front is a member of the definite peripheral location list. In addition, each location from the close front to the open front is a member of the candidate peripheral location list. A number of links from the current location node to the close front is smaller than a number of links from the current location node to the open front. Accordingly, in this example, the locations L0, L1, and L2 are stored (or listed) in the definite peripheral location list, and the locations L3, L4, and L5 are stored (or listed) in the candidate peripheral location list. Further, a close total data size is 2.0K+1.2K+0.3K=3.5K<8.0K, and is less than the limit value of 8.0.

FIG. **18** illustrates a state after the updating process of steps S**35** through S**39** illustrated in FIG. **15** is performed for the first time with respect to the place graph illustrated in FIG. **17**. In this example, from the candidate peripheral location list, the location having the largest link value from the parent location node is the location L3, the link value S**13** is 0.5, and the estimated value does not exceed the limit value even when the data size of the location L3 is added to the close total data size. The close total data size is 2.0K+1.2K+0.3K+2.2K=5.7K<8.0K, and is less than the limit value of 8.0. Accordingly, the location L3 is selected as a candidate for the close process, and the open process is performed with respect to locations L6 and L7 linked to the location L3. As a result, the locations L0, L1, L2, and L3 are stored (or listed) in the definite peripheral location list, and the locations L4, L5, L6, and L7 are stored (or listed) in the candidate peripheral location list.

FIG. **19** illustrates a state after the updating process of steps S**35** through S**39** illustrated in FIG. **15** is performed for the second time with respect to the place graph illustrated in FIG. **18**. In this example, from the locations L4, L5, L6, and L7 stored in the candidate peripheral location list, the location having the largest link value from the parent location node is the location L6, the link value S**36** is 0.6, and the estimated value does not exceed the limit value even when the data size of the location L6 is added to the close total data size. The close total data size is 2.0K+1.2K+0.3K+2.2K+1.0K=6.7K<8.0K, and is less than the limit value of 8.0. Accordingly, the location L6 is selected as a candidate for the close process. In this case, there is no location with respect to which the open process is to be newly performed, because there is no location that is linked to the location L6 and has not yet been subjected to the close process nor the open process. As a result, the locations L0, L1, L2, L3, and L6 are stored (or listed) in the definite peripheral location list, and the locations L4, L5, and L7 are stored (or listed) in the candidate peripheral location list.

FIG. **20** illustrates a state after the updating process of steps S**35** through S**39** illustrated in FIG. **15** is performed for the third time with respect to the place graph illustrated in FIG. **19**. In this example, from the locations L4, L5, and L7 stored in the candidate peripheral location list, the location having the largest link value from the parent location node is the location L5, and the link value S**25** is 1.6. In this case, when the data size of the location L5 is added to eth close total data size, the estimated value exceeds the limit value. The close total data size is 2.0K+1.2K+0.3K+2.2K+1.0K+1.6K=8.3K>8.0K, and is exceeds the limit value of 8.0. The locations L0, L1, L2, L3, L6, and L5 are stored (or listed) in the definite peripheral location list, and the locations L4 and L7 are stored (or listed) in the candidate peripheral location list. In addition, because the close total data size exceeds the limit value (that is, judgment result in step S**37** becomes YES), the updating process of steps S**35** through S**39** ends, and it is judged (step S**40**) that the locations L0, L1, L2, L3, and L6 other than the location L5 stored in the definite peripheral location list are the peripheral locations to be extracted.

Therefore, the server **21** extracts the peripheral locations by updating each location that is a member of the definite peripheral location list and exists from the current location to the close front in the place graph, and updating each location that is a member of the candidate peripheral location list and exists from the close front to the open front in the place graph, using the current location of the mobile terminal **1** as the query. In other words, the server **21** extracts the peripheral locations by repeating the updating process in which the locations up to each of the close front and the open front are added to or deleted from the definite peripheral location list and the candidate peripheral location list. In addition, the server **21** includes in the peripheral location model a close front flag that is added to the extracted peripheral location and identifies this extracted peripheral location as being a location up to the close front, and transmits the data of the peripheral location model to the mobile terminal **1**. In this example, the close front flag is included in the data of the peripheral location model by the transmitting process, however, the close front flag may of course be included in the data of the peripheral location model by the extracting process. When the mobile terminal **1** moves and the mobile terminal **1** identifies from the close front flag that the new current location after the mobile terminal **1** moves is the close front or a vicinity of the close front, the mobile terminal **1** requests the peripheral location model with respect to the server **21**. In response to this request from the mobile terminal **1**, the server **21** transmits the data of the extracted peripheral location model to the mobile terminal **1**.

FIG. **21** is a diagram illustrating another example of the data structure of the location model. In FIG. **21**, those parts that are the same as those corresponding parts in FIG. **5** are designated by the same reference numerals, and a description thereof will be omitted. The data structure of the location model illustrated in FIG. **21** includes, in addition to the data of the peripheral location model to be transmitted from the server **21** to the mobile terminal **1**, the close front tag that identifies whether each location node in the place graph is a location node (hereinafter also referred to as a "close front location node") from the current location node to the close front. When a user holding the mobile terminal **1** moves after the peripheral location model is downloaded from the server **21** to the mobile terminal **1**, the mobile terminal **1** can judge whether the new current location after the mobile terminal **1** moves is in the vicinity of the close front, based on the close front tag of the peripheral location model. In a case in which the mobile terminal **1** judges that the new current location is in the vicinity of the close front, the mobile terminal **1** can make a download request for the peripheral location model with respect to the server **21**.

Next, a description will be given of another example of the updating process to update the peripheral location model at the mobile terminal, by referring to FIG. **22**. FIG. **22** is a flow chart for generally explaining processes at the server and the mobile terminal. In FIG. **22**, steps S**31** through S**39** are executed by the processor of the mobile terminal **1**, such as the CPU **11**, and steps S**41** through S**43** are executed by the processor of the server **21**, such as the PU.

In FIG. **22**, when a power of the mobile terminal **1** is turned ON, in step S**31**, the CPU **11** of the mobile terminal **1** makes an inquiry as to whether the peripheral location model is stored in the storage unit **12** of the mobile terminal **1**, that is, whether the mobile terminal **1** stores the peripheral location model. In step S**32**, the CPU of the mobile terminal **1** judges whether the mobile terminal **1** stores the peripheral location model, based on a response to the inquiry. The process advances to step S**33** when the judgment result in step S**32** is YES, and the process advances to step S**38** which will be described later when the judgment result in step S**32** is NO.

In step S**33**, the CPU **11** of the mobile terminal **11** detects a current location of the mobile terminal **11**. In step S**34**, the CPU **11** of the mobile terminal **1** judges whether the detected current location is unknown, and the process advances to step S**35** when the judgment result is NO, and the process advances to step S**38** which will be described later when the judgment result is YES. In step S**35**, the CPU **11** of the mobile terminal **1** judges whether the current location is the close front location up to the close front, and the process advances to step S**36** when the judgment result is YES, and the process advances to step S**37** when the judgment result is NO. In step S**36**, the CPU **11** of the mobile terminal **1** transmits the current location to the server **21**, in order to make the update request (or download request) for the peripheral location model with respect to the server **21**. In step S**37**, the CPU **11** of the mobile terminal **1** judges that the current location is not the close front location up to the close front, and the process returns to step S**33**. In step S**38**, the CPU **11** of the mobile terminal **1** acquires and transmits to the server **21** the check-in data including the MAC address of each AP and the RSSI from the WiFi scan data, in order to makes the request (download request) for the peripheral location model with respect to the server **21**.

On the other hand, when the check-in data, that is, the request for the peripheral location model, from the mobile terminal **1** is received at the server **21** in step S**41**, the CPU of the server **21** detects the current location of the mobile terminal **1** from the received check-in data. In step S**42**, the CPU of the server **21** extracts the peripheral location model of the current location detected in step S**42**, or the peripheral location model of the current location transmitted from the mobile terminal **1** in step S**36** and received by the server **21**. In step S**43**, the CPU of the server **21** transmits the extracted peripheral location model to the mobile terminal **1**.

When the peripheral location model from the server **21** is received by the mobile terminal **1** in step S**39**, the CPU **11** of the mobile terminal **11** stores the received peripheral location model in the storage unit **12** of the mobile terminal **1**, and updates the location model.

Accordingly, in a case in which the mobile terminal **1** stores the location model, the mobile terminal **1** detects the current location, and when the detected current location is unknown, the mobile terminal **1** transmits the check-in data to the server **21** in order to request the peripheral location model. In addition, in a case in which the mobile terminal **1** does not store the location model, the mobile terminal **1** requests the peripheral location model to the server **21** by transmitting the check-in data to the server **21**. In these two cases, the server **21** extracts the peripheral location model of the peripheral location in the periphery of the current location, detected based on the check-in data, and transmits the extracted peripheral location model to the mobile terminal **1**.

On the other hand, in the case in which the mobile terminal **1** stores the location model, the mobile terminal **1** detects the current location, and the detected current location is the close front location, the mobile terminal **1** transmits the current location with respect to the server **21** in order to request the peripheral location model. In this case, the server **21** extracts the peripheral location model of the peripheral location in the periphery of the current location, and transmits the extracted peripheral location model to the mobile terminal **1**.

In the case in which the mobile terminal **1** stores the location model, the mobile terminal **1** detects the current location, and the detected current location is not the close front location, the mobile terminal **1** does not make the update request for the peripheral location model with respect to the server **21**.

FIG. **23** is a diagram for explaining in more detail processes of steps S**42** and S**43** performed at the server **21**. Data referred to by the processes illustrated in FIG. **23** include a peripheral location name list **2000-1** of the location models already stored in the mobile terminal **1** and received together with the request for the peripheral location model from the mobile terminal **1**, and a peripheral location name list **200-2** of the location models that is generated by the location model extracting process of the server **21** and is to be stored in the mobile terminal **1**. For example, the peripheral location name lists **2000-1** and **2000-2** may be stored in the storage unit of the server **21**. In addition, data generated by the processes illustrated in FIG. **23** include a location name list **2001** of the locations that have become unnecessary and are to be deleted, and a location name list **2002** of the locations that are to be newly added. For example, the location name lists **2001** and **2002** may be stored in the storage unit of the server **21**.

In step S**421** illustrated in FIG. **23**, the CPU of the server **21** extracts the location name list **2001** of the locations to be deleted at the mobile terminal **1**, based on the peripheral location name list **2000-1**, and stores the extracted location name list **2001** in the storage unit of the server **21**. In step S**422**, the CPU of the server **21** extracts the location name list **2002** of the locations to be added at the mobile terminal **1**, based on the peripheral location name list **2000-2**, and stores the extracted location name list **2002** in the storage unit of the server **21**. In step S**431**, the CPU of the server **21** serializes the extracted location name lists **2001** and **2002**, in order to generate serial transmitting data. In step S**432**, the CPU of the server **21** transmits the serial transmitting data to the mobile terminal **1**.

FIG. **24** is a diagram for explaining in more detail a process of step S**39** performed at the mobile terminal **1**. In step S**391** illustrated in FIG. **24**, the CPU **11** of the mobile terminal **1** receives the serial transmitting data from the server **12**. In step S**392**, the CPU **11** of the mobile terminal **1** deserializes the serial transmitting data received from the server **12**, in order to generate a location name list **1201** of the locations to be deleted and a location name list **1202** of the locations to be added. The location name lists **1201** and **1202** that are generated by the deserialization are the same as the location name lists **2001** and **2002**, respectively, before the serialization is performed at the server **21**. In step S**393**, the CPU **11** of the mobile terminal **1** performs a deleting process to delete the location names that are to be deleted from the location model stored in the storage unit **12** of the mobile terminal **1**, based on the location name list **1201**. In step S**394**, the CPU **11** of the mobile terminal **1** performs an adding process to add the location names that are to be added to the location model stored in the storage unit **12** of the mobile terminal **1**, based on the location name list **1202**. Hence, even when the mobile terminal **1** moves, it is possible to automatically update the peripheral location models to be used by the mobile terminal **1** for the position estimation.

According to the updating process illustrated in FIGS. **22** through **24**, the server **21** does not transmit all of the peripheral location models to the mobile terminal **1**, and transmits to the mobile terminal **1** only the difference data corresponding to the difference between the location model already stored in the mobile terminal **1** and the new peripheral location model to be updated. For this reason, the amount of data transmitted and received between the server **21** and the mobile terminal **1** can be reduced, the communication time associated with the updating process can be shortened, and the power consumption associated with the updating process at the mobile terminal **1** can be reduced. In a case in which the mobile terminal **1** is used in a state held by the user who is free to move, the mobile terminal **1** is powered by a battery. Hence, by reducing the power consumption associated with the updating process at the mobile terminal **1**, it is possible to suppress the wear of the battery and extend the time for which the mobile terminal **1** is continuously usable by the user.

According to the embodiments described above, it is possible to reduce a storage capacity for storing the location models in the terminal apparatus, without sacrificing the position estimating accuracy.

The description above use terms such as “determine”, “identify”, or the like to describe the embodiments, however, such terms are abstractions of the actual operations that are performed. Hence, the actual operations that correspond to such terms may vary depending on the implementation, as is obvious to those skilled in the art.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A location model updating apparatus comprising:

a storage unit; and

a processor configured to

generate attribute data in which an attribute of a location is represented by a location name and a data size of a location model, and an attribute between locations is represented by a similarity between the locations;

extract a peripheral location by including each location from a current location of a terminal apparatus to a first front as a member of a definite peripheral location list, including each location from the first front to a second front as a member of a candidate peripheral location list, and updating each location that is a member of the definite peripheral location list and exists from the current location to the first front, and each location that is a member of the candidate peripheral location list and exists from the first front to the second front, using the current location of the terminal apparatus as a query; and

transmit data of a peripheral location model of the peripheral location that is extracted, to the terminal apparatus, by including in the peripheral location model a flag identifying the peripheral location that is extracted as a location up to the first front.

2. The location model updating apparatus as claimed in claim **1**, wherein the processor transmits, to the terminal apparatus, difference data between the location model stored in the terminal apparatus and received from the terminal apparatus, and the peripheral location model extracted by the processor.

3. The location model updating apparatus as claimed in claim **1**, wherein the processor transmits the data of the peripheral location model of the peripheral location that is extracted, to the terminal apparatus, in response to a request received from the terminal apparatus when the terminal apparatus identifies from the flag that a new current location after the terminal apparatus moves is the first front or a vicinity of the first front.

4. The location model updating apparatus as claimed in claim **1**, wherein

the attribute between the locations includes similarities of features between the locations, and

the features include features related to frequencies of an observing state and an observation missing state of signals from base stations at the terminal apparatus, and features related to received signal strengths at the terminal apparatus.

5. A position estimating method to estimate a position of a terminal apparatus that is communicable with a plurality of base stations, comprising:

estimating, in the terminal apparatus, the position of the terminal apparatus based on a location model stored within the terminal apparatus;

updating, in the terminal apparatus, the location model based on data downloaded from a server; and

performing, in a server, a location model updating process to update the location model stored in a storage unit of the server based on data received from the terminal apparatus, and a transmitting process,

wherein the location model updating process includes

generating attribute data in which an attribute of a location is represented by a location name and a data size of a location model, and an attribute between locations is represented by a similarity between the locations;

extracting a peripheral location by including each location from a current location of a terminal apparatus to a first front as a member of a definite peripheral location list, including each location from the first front to a second front as a member of a candidate peripheral location list, and updating each location that is a member of the definite peripheral location list and exists from the current location to the first front, and each location that is a member of the candidate peripheral location list and exists from the first front to the second front, using the current location of the terminal apparatus as a query; and

wherein the transmitting process includes

transmitting data of a peripheral location model of the peripheral location that is extracted, to the terminal apparatus, by including in the peripheral location model a flag identifying the peripheral location that is extracted as a location up to the first front.

6. The position estimating method as claimed in claim **5**, wherein the transmitting process transmits, to the terminal apparatus, difference data between the location model stored in the terminal apparatus and received from the terminal apparatus, and the peripheral location model extracted by the server.

7. The position estimating method as claimed in claim **5**, wherein

the terminal apparatus transmits a request with respect to the server when the terminal apparatus identifies from the flag that a new current location after the terminal apparatus moves is the first front or a vicinity of the first front. and

the server transmits the data of the peripheral location model of the peripheral location that is extracted, to the terminal apparatus, in response to the request received from the terminal apparatus.

8. The position estimating method as claimed in claim **5**, wherein

the attribute between the locations includes similarities of features between the locations, and

the features include features related to frequencies of an observing state and an observation missing state of signals from base stations at the terminal apparatus, and features related to received signal strengths at the terminal apparatus.

9. A non-transitory computer-readable storage medium having stored therein a program for causing a computer to execute a process to update a location model based on data received from a terminal apparatus, the process comprising:

generating attribute data in which an attribute of a location is represented by a location name and a data size of a location model, and an attribute between locations is represented by a similarity between the locations;

extracting a peripheral location by including each location from a current location of a terminal apparatus to a first front as a member of a definite peripheral location list, including each location from the first front to a second front as a member of a candidate peripheral location list, and updating each location that is a member of the definite peripheral location list and exists from the current location to the first front, and each location that is a member of the candidate peripheral location list and exists from the first front to the second front, using the current location of the terminal apparatus as a query; and

transmitting data of a peripheral location model of the peripheral location that is extracted, to the terminal apparatus, by including in the peripheral location model a flag identifying the peripheral location that is extracted as a location up to the first front.

10. The non-transitory computer-readable storage medium as claimed in claim **9**, wherein the transmitting transmits, to the terminal apparatus, difference data between the location model stored in the terminal apparatus and received from the terminal apparatus, and the peripheral location model extracted by the extracting.

11. The non-transitory computer-readable storage medium as claimed in claim **9**, wherein the transmitting transmits the data of the peripheral location model of the peripheral location that is extracted, to the terminal apparatus, in response to a request received from the terminal apparatus when the terminal apparatus identifies from the flag that a new current location after the terminal apparatus moves is the first front or a vicinity of the first front.

12. The non-transitory computer-readable storage medium as claimed in claim **9**, wherein

the attribute between the locations includes similarities of features between the locations, and

the features include features related to frequencies of an observing state and an observation missing state of signals from base stations at the terminal apparatus, and features related to received signal strengths at the terminal apparatus.

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